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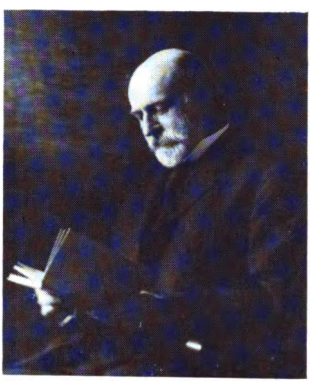

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THE

Mineralogical Magazine

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY

OF

GREAT BRITAIN AND IRELAND.

VOLUME IV.

LONDON:
SIMPKIN, MARSHALL, & Co., STATIONERS' HALL COURT.
TRURO:
LAKE & LAKE, PRINCES STREET.

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Mineralogical Magazine.

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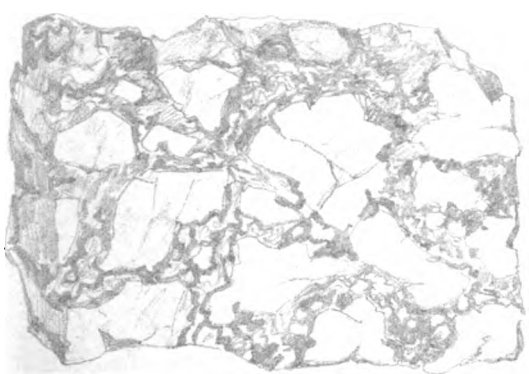

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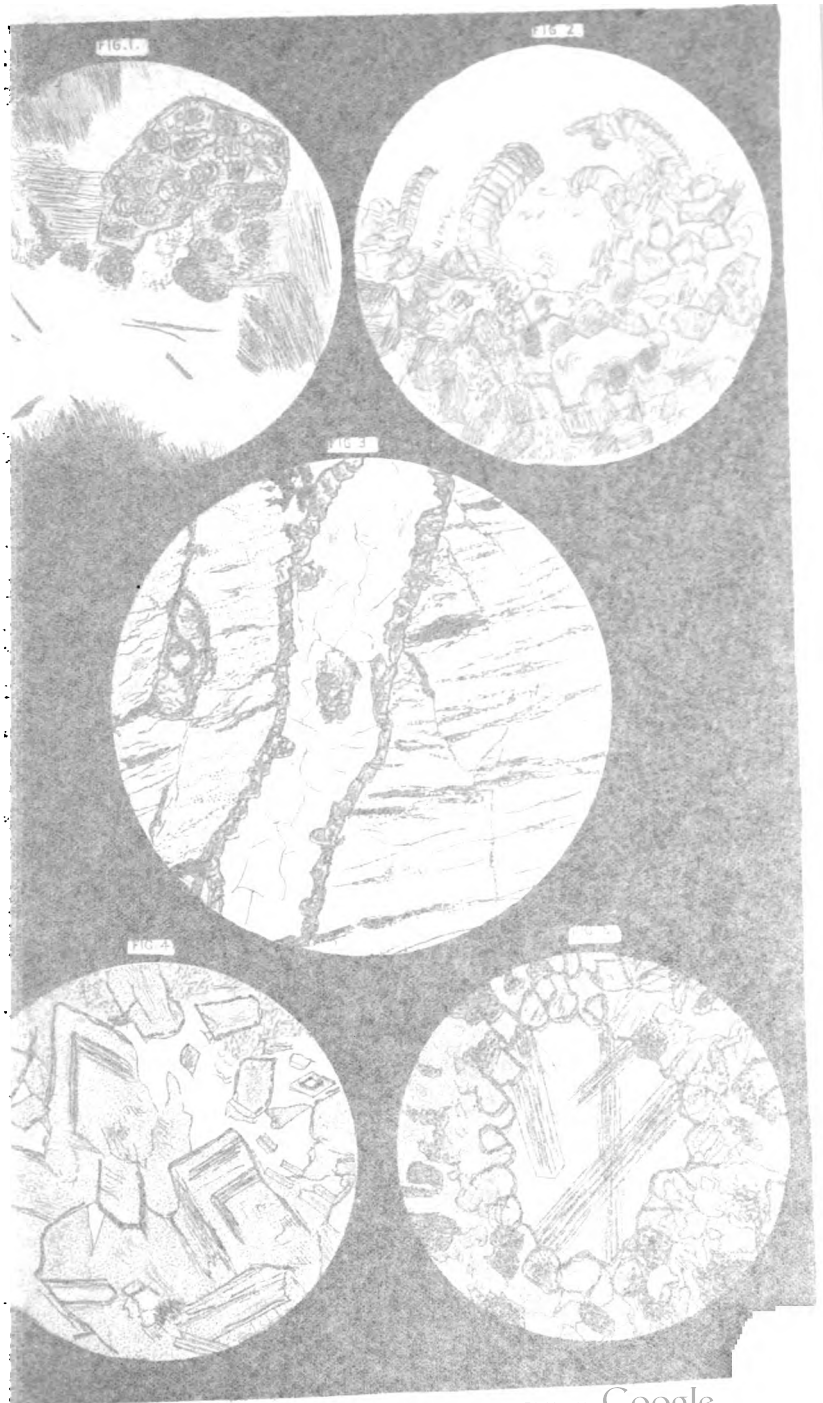

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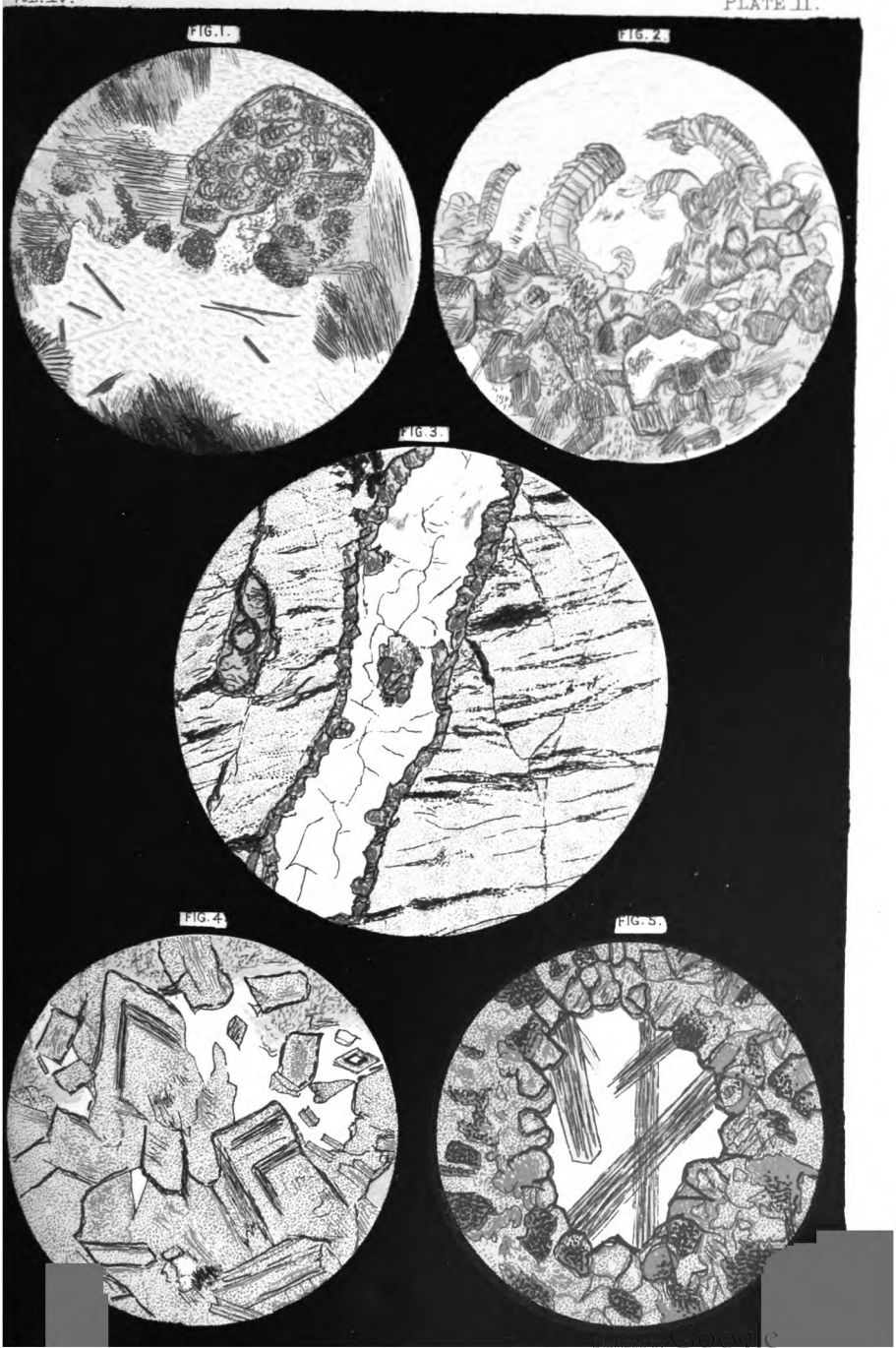

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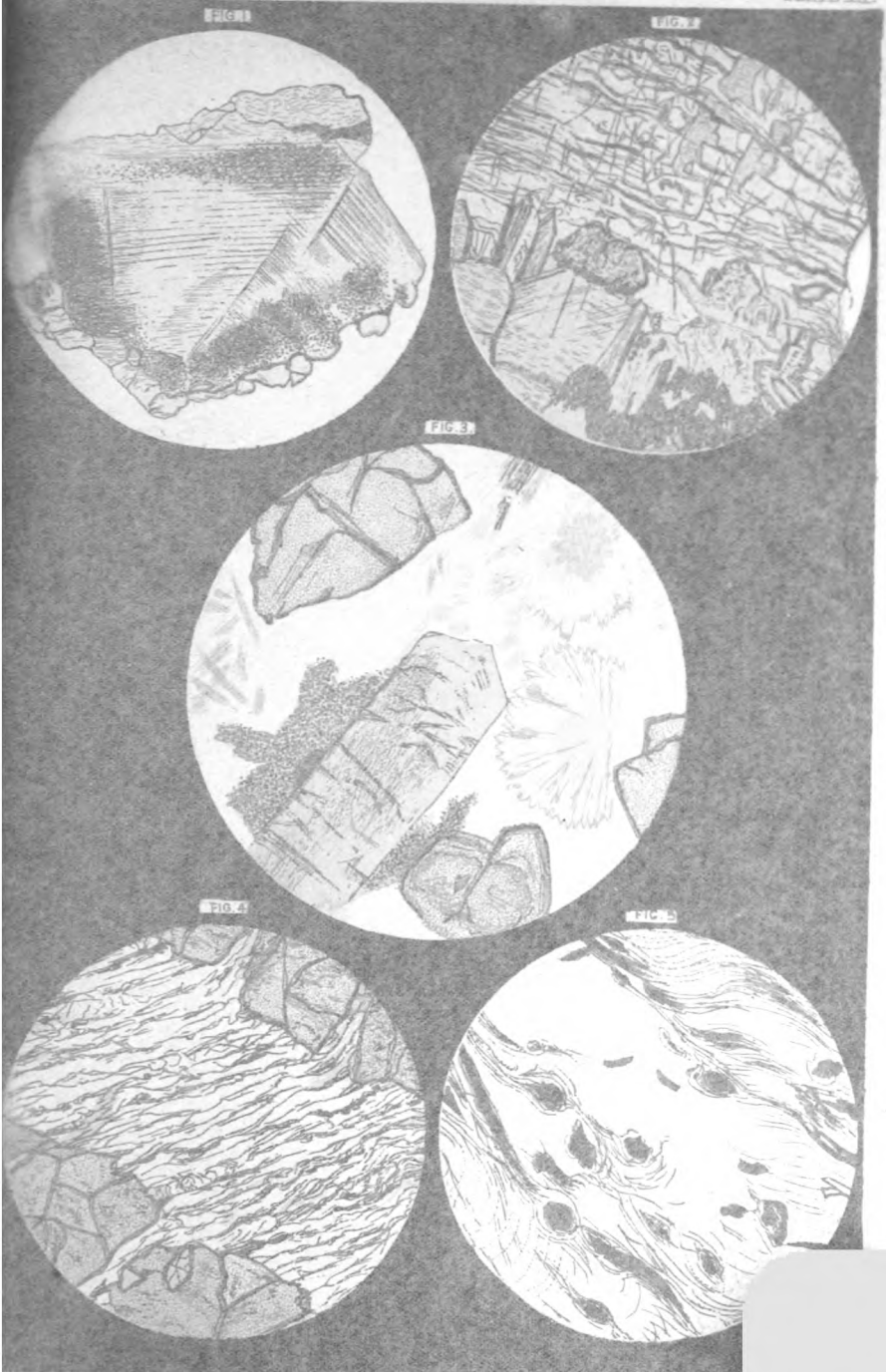

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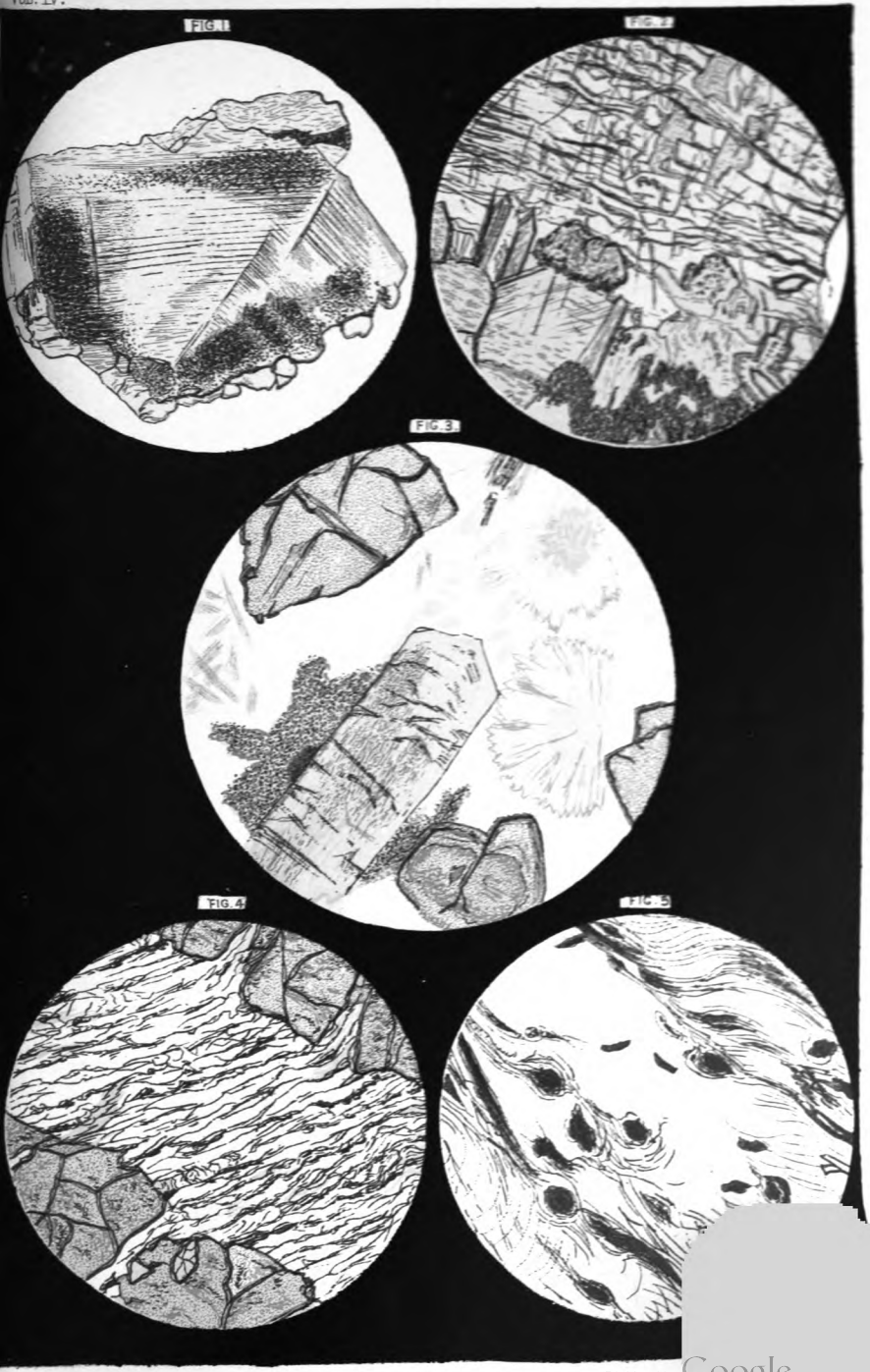

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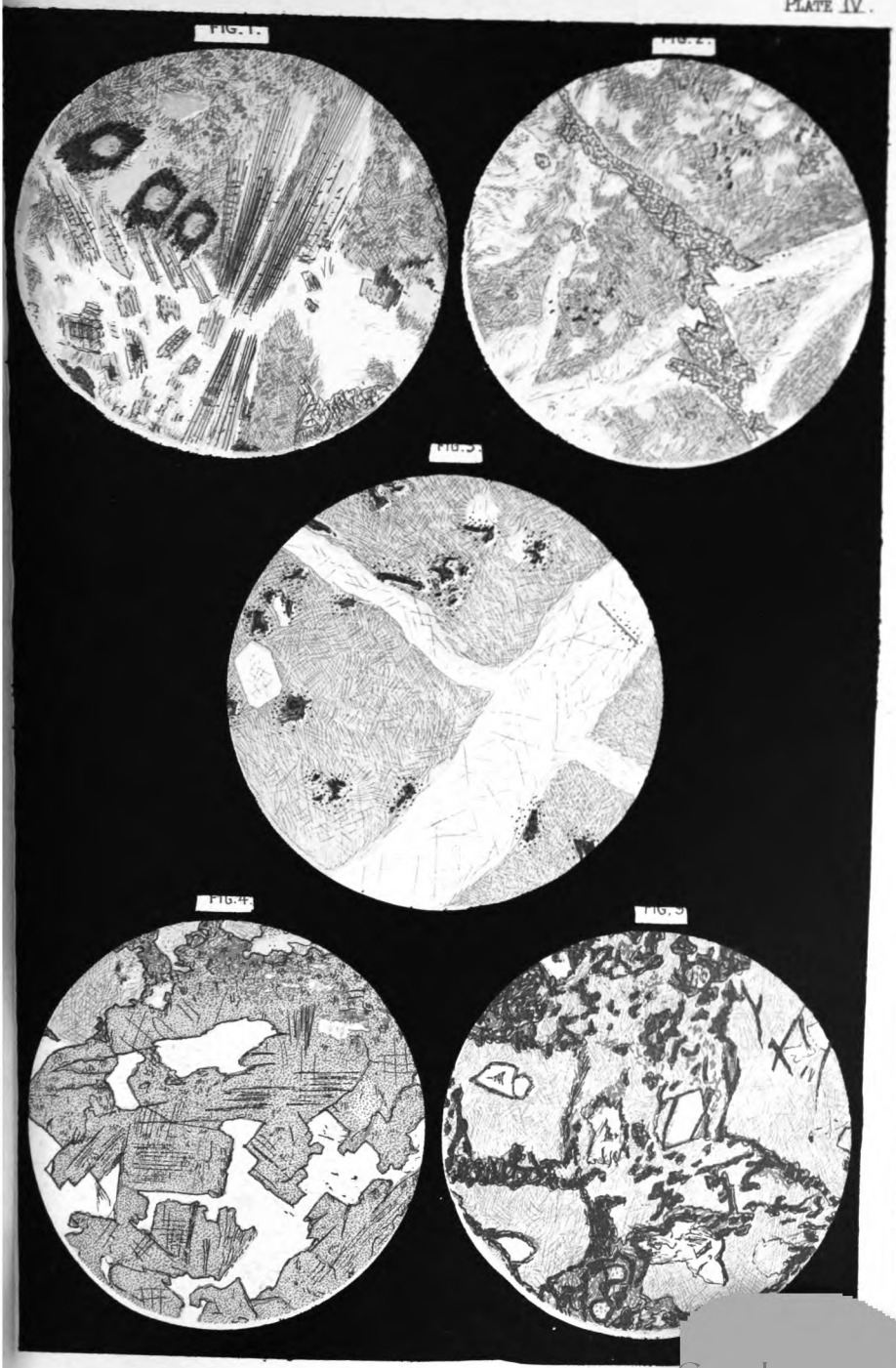

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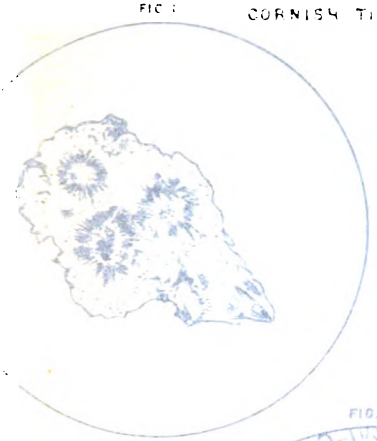
FIG. 1. CORNISH TIN-STONES. FIG. 2.



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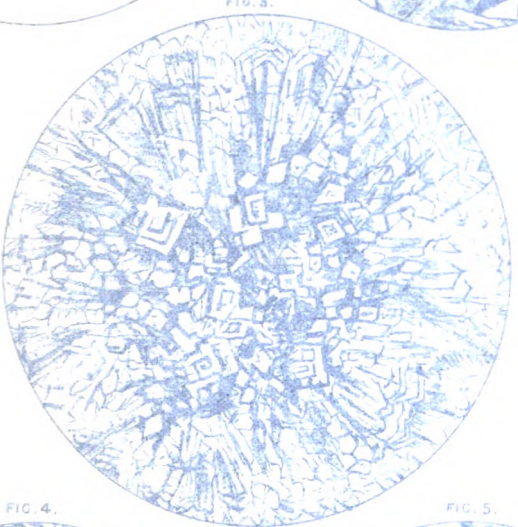

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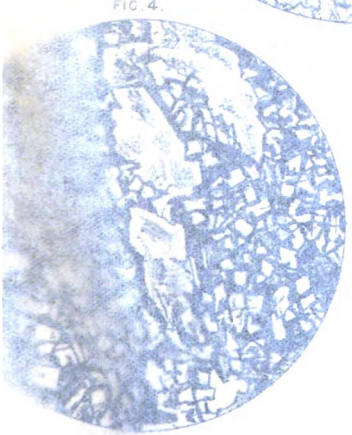

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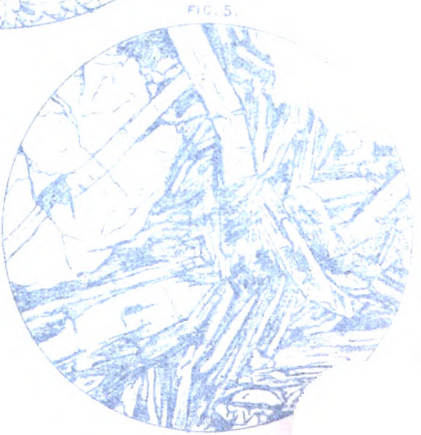

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CORNISH TIN-STONES.

FIG. 1.

FIG. 2.

FIG. 3.

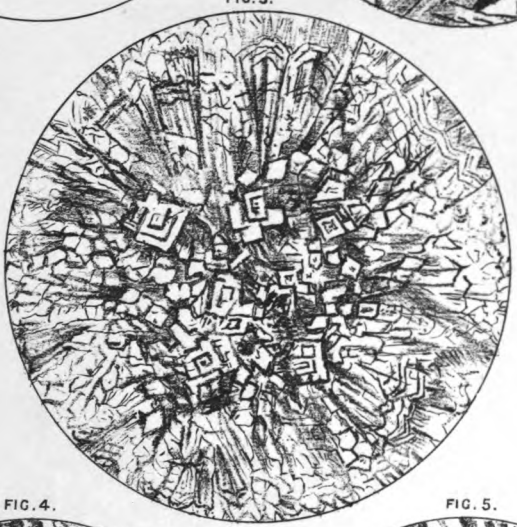

FIG. 4.

FIG. 5.

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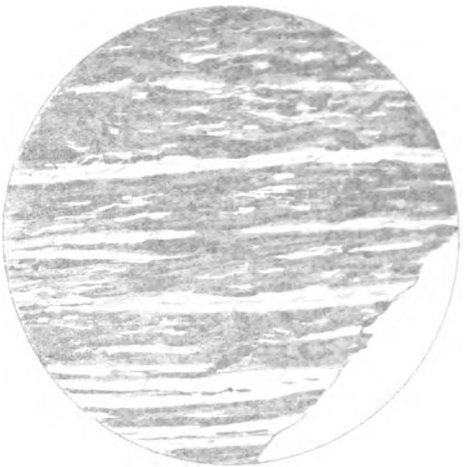

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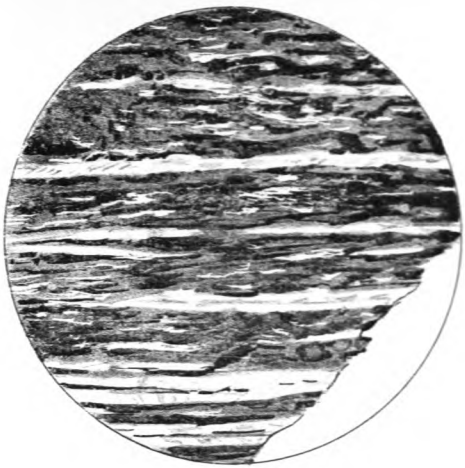
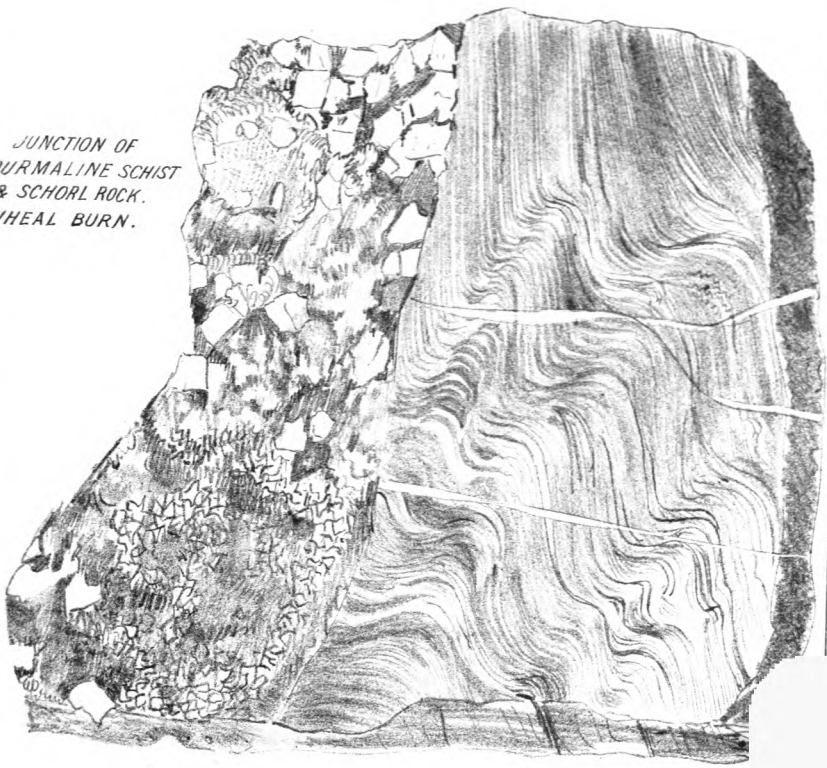
CORNISH TIN STONES.



TOURMALINE SCHIST.
PARK OF MINES.



JUNCTION OF
TOURMALINE SCHIST
& SCHORL ROCK.
WHEAL BURN.

J.H.C. Del.

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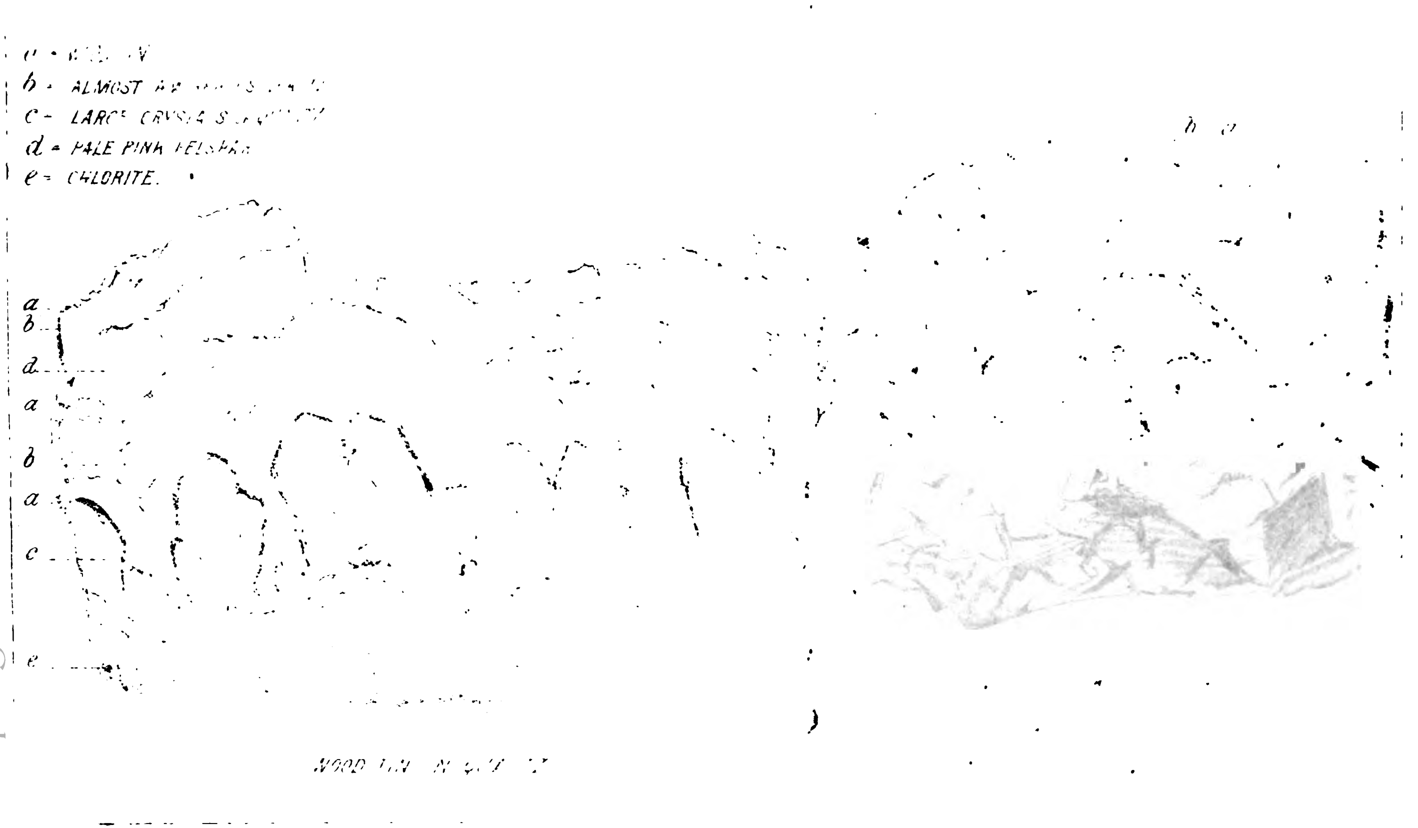
b = ALMOST
d = PALE PINK
e = CHLORITE.
a
b
d
a
b
a
c
e

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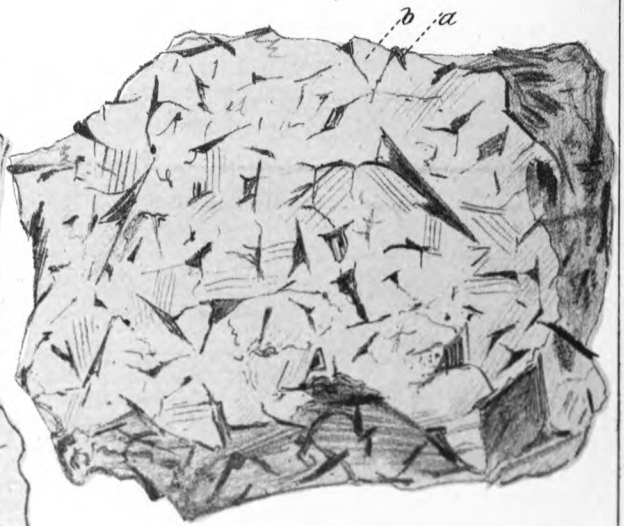
CORNISH TIN STONES.

a = WOOD TIN.
b = ALMOST AMORPHOUS QUARTZ.
c = LARGE CRYSTALS OF QUARTZ.
d = PALE PINK FELSPAR.
e = CHLORITE.

WOOD TIN IN QUARTZ.



BROWN WOOD TIN IN PINK FELSPAR. NAT. SIZE.

a = WOOD TIN.
b = FELSPAR.

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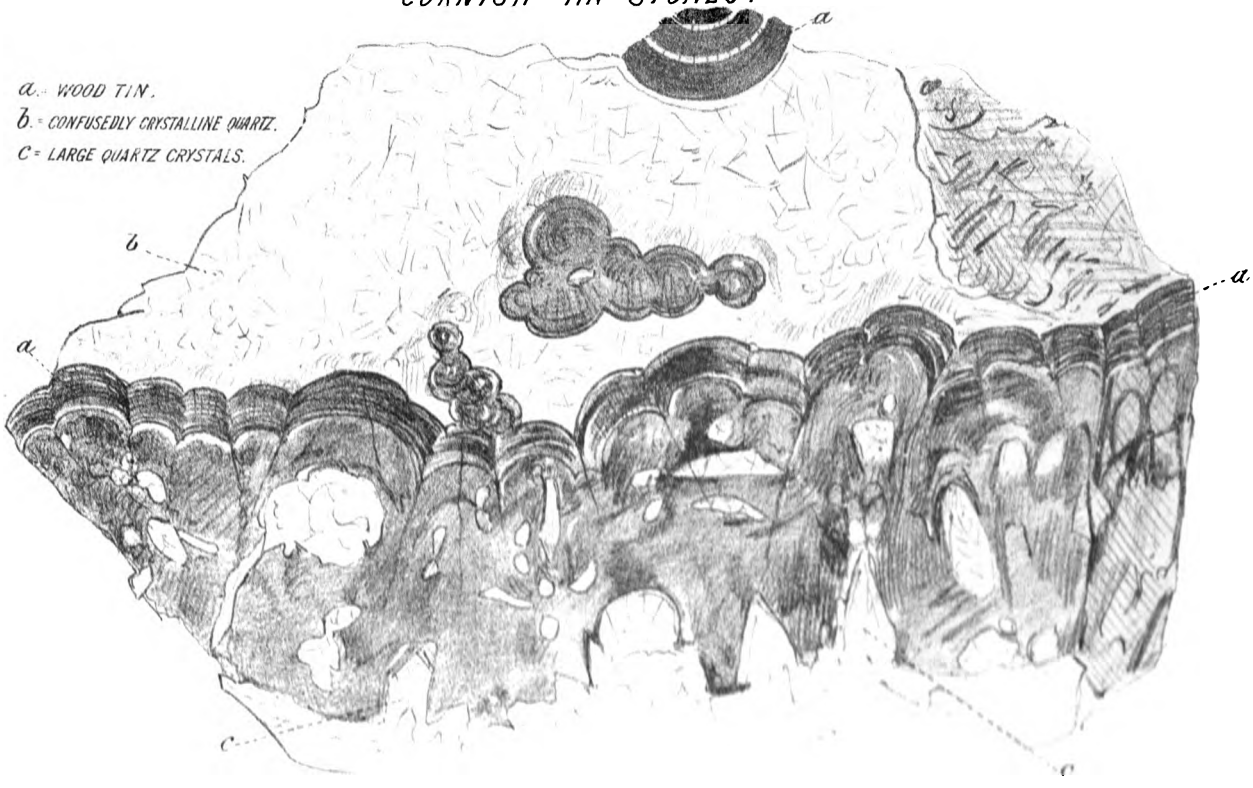
CORNISH TIN STONES.



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WOOD TIN IN FELSPAR & QUARTZ.

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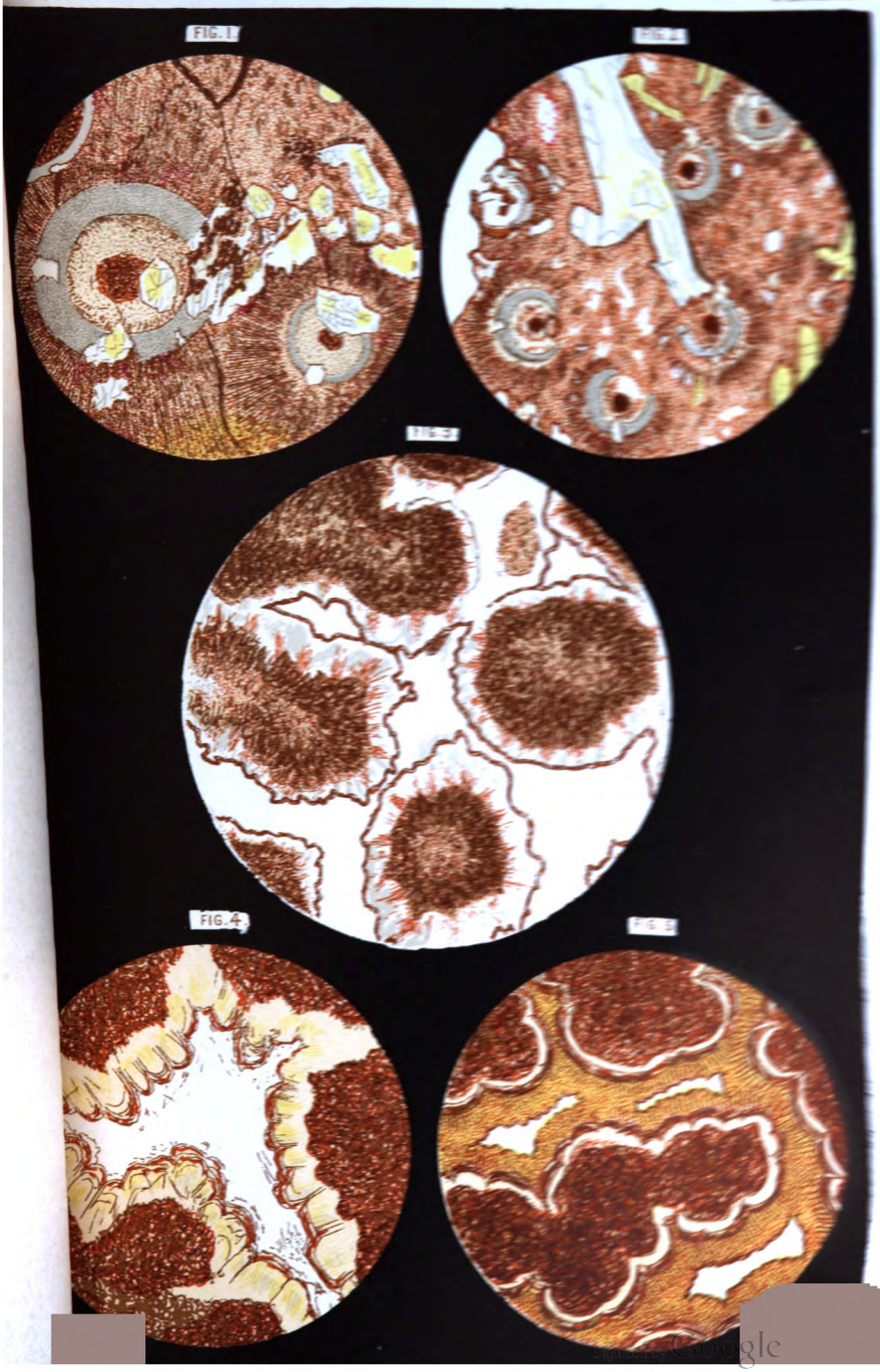

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PROCEEDINGS

OF THE

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND.

1880.

EXCERPT MINUTES OF COUNCIL MEETING

Held in the University of Edinburgh, April 5th, 1880.

Prof. M. F. Heddle, F.R.S.E., *President,* in the Chair.

Professor F. J. Wiik, of Helsingfors, and Mr. Richard Pearce, of Denver City, Colorado, were elected as Ordinary Members.

ORDINARY MEETING.

Held in the University of Edinburgh, April 5th, 1880

(By permission of the *Senatus Academicus.*)

Prof. M. F. Heddle, F.R.S.E., in the Chair.

Prof. A. Geikie, F.R.S., read a paper "On the microscopic structure of some vitreous basalts." The paper was beautifully illustrated by diagrams, and by a series of large coloured drawings—the work of the author.

Mr. J. B. Hannay, F.C.S., gave an account of his experiments with a view to the production of artificial diamonds, and exhibited some fragments of the diamonds produced.

The authors were thanked for their respective papers.

LOCAL MEETING.

Held at Dundee, in the Albert Hall, Friday, April 9th, 1880.

Prof. M. F. Heddle, F.R.S.E., in the Chair.

Dr. Heddle gave an address in which he dwelt on the origin of mineralogical research in Scotland. He then described the steps which led to the formation of the Mineralogical Society, and gave an outline of the mineralogy of the neighbourhood of Dundee.

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The Rev. W. W. Peyton, of Broughty Ferry, was elected Local Secretary for the Central District of Scotland, in accordance with Rule 24.

EXCERPT MINUTES OF COUNCIL MEETING.

Held at the Meteorological Office, 116, *Victoria Street, London, S.W., June 1st*, 1880.

PROF. T. G. BONNEY, F.R.S., *Vice-President*, in the Chair.

The Secretary reported the deaths of Professor Sismonda, Rev. J. Clifton Ward, F.G.S., and Professor Ansted, F.R.S., members of the Society.

The Secretary reported that the Rev. W. W. Peyton had been elected Local Secretary for the central district of Scotland, at a meeting of Scotch members held in the Albert Hall, Dundee, on the 9th April, in accordance with Rule 24; and the election was confirmed by the Council.

Messrs. Wm. Neish Walker, F.G.S., of Newport, Fife; Alexander Murray, F.G.S., of St. John's, Newfoundland, Director of the Geol. Survey of N.F.; Geo. S. Mackenzie, Ph. D. of Dundee; and Hjalmar Furuhjelm, of Helsingfors, Gov. Inspector of Mines for Finland, were elected as Ordinary Members of the Society.

Mr. Robert M. Heddle, of St. Andrews, was elected as an associate.

The Balance Sheet and Statement of Assets and Liabilities as here appended, was presented by the Secretary, and adopted.

The Annual Meeting was fixed for the month of August, to be held at Swansea during the Meeting of the British Association.

It was resolved to recommend the re-election of all the officers, and to propose Prof. Church and Messrs. T. W. Danby, J. S. Merry, and J. F. Walker, as members of Council in place of the four retiring members, Messrs. T. Davies, T. M. Hall, M. H. Johnson, and Dr. Oxland.

GENERAL MEETING.

Held at 116, *Victoria Street, June 1st*, 1880.

PROFESSOR T. G. BONNEY, F.R.S., *Vice-President*, in the Chair.

The following papers were read :—

"On a new face on crystals of Stilbite from Scotland and Western Australia," by Prof. M. F. Heddle, F.R.S.E.

"On a portable chemical cabinet for quantitative work," by A. E. Arnold, communicated by J. H. Collins.

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"On kaolinite and kaolin," by J. H. Collins, F.G.S.

"On some substances which may prove to be new minerals," by Prof. M. F. Heddle, F.R.S.E.

"Further notes on mineral growth at ordinary temperatures," by T. A. Readwin, F.G.S.

Mr. F. W. Rudler exhibited a very large crystal of enstatite and a specimen of the new mineral Herrengrundite.

Mr. Semmons exhibited a specimen of Linnæite associated with Millerite in a nodule of clay iron-stone from the Rhondda Valley. The occurrence of Linnæite in this locality and association was first observed by Mr. Wm. Terril of Swansea.

Mr. J. R. Gregory exhibited part of a fine meteorite which fell at Esterville, Emmet Co., Iowa, U.S.A., on the 10th May, 1879.

Votes of thanks were passed to the authors of the papers read, to the Vice-President for his conduct of the Meeting, and to Mr. R. H. Scott, F.R.S., for the use of the room in which the meeting was held.

LIST OF BOOKS RECEIVED FROM MARCH TO JUNE, 1880.

From *The Dundee Naturalists' Society, Dundee.*
Reports, 1877 to 1879.
Catalogue of 3rd Exhibition.

From *Reale Comitato Geologico, Rome.*
Bolletino, 1 to 4, 1880.

From *J. P. Howley, St. John's, Newfoundland.*
The Geology of Newfoundland, by J. P. H.

From *Prof. Groth, Strasburg.*
Zeitschrift fur Kryst. und. Min., IV, 4.

From *Prof. Dana, Newhaven.*
American Journ. Science, April to June, 1880.

From *Soc. Min. de France, Paris.*
Bulletin III, 3 to 5, vol. III.

From *Prof. Tschermak, Vienna.*
Min. und. Pet. Mittheilungen, II, 6.

From *Soc. Toscan di Scienze Naturali Pisa.*
Procesi verbali pp. 37-52.

From *M. Emile Bertrand, Paris,*
Proprietés optiquès de la Brochantite, by E. B.

From *Prof. Kjerulf. Christiania.*
Die Geologie des Sudlichen und Mittleren Norwegen, by T. K.

From *M. Delesse, Paris.*
Carte Agronomique du Dep. de Seine, et Marne, by M.D.

From *Academy of Nat. Sciences, Philadelphia.*
Proceedings I, II, III, 1879.

From *Soc. Cientifica Argentina, Buenos Ayres.*
Anales, April, 1880.

Anonymous—Sitzungberichte der koniglichbayer Akad. der Wissenschaften, March 20, 1880, with obituary notices of Dové, Lamont, Mohr, Griesebach, Cotta, and Brandt.

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Mineralogical Society of Great Britain and Ireland.

STATEMENT OF RECEIPTS AND EXPENDITURE TO DECEMBER, 31st, 1879.

RECEIPTS.

Dr.	£	s.	d.
By Balances from 1878	54	18	5
,, Composition Fee	10	10	0
,, Subscriptions for 1879	86	13	0
,, ,, Arrears	36	4	0
,, Magazines sold	15	8	0
,, Dividends on Investments	3	10	6
	£207	3	11

EXPENDITURE.

Cr.	£	s.	d.
To Lake & Lake, for Printing Magazines, &c.	72	3	6
,, Carriage of Parcels, Postage, &c.	6	4	2
,, Postage of Magazines	6	7	7
,, Travelling Expenses	19	15	0
,, Clerical work and sundries	3	6	6
,, Meeting Expenses	1	16	0
,, Letcher, for case of Shelves	2	15	0
,, Printing and Stationery	10	4	0
,, Editing Magazine	20	0	0
,, Investments 3 p.c. Consols	23	10	6
Balance	41	1	8
	£207	3	11

Examined and found correct
March 23rd, 1880.

BENEDICT KITTO.
F. W. RUDLER.

ASSETS.

	£	s.	d.
Balance	41	1	8
Subscriptions (considered good)	50	0	0
Due for Magazines and Maps sold	12	12	5
Estimated value of Stock, 1-3rd selling price	122	0	10
	£225	14	11

LIABILITIES.

	£	s.	d.
Lake and Lake, for Map	64	11	3
Do. for Magazines	64	19	0
Sundry Bills (estimated)	5	0	0
Balance	91	4	8
	£225	14	11

TRUST ACCOUNT, DECEMBER 31st, 1879.

3 per cents Consols	£118	3	0
Investment of £23 10s. 6d.	24	10	2
	£142	13	2

(Signed) P. DUDGEON, for self and Co-Trustee.

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EXCERPT MINUTES OF COUNCIL MEETING.

Held in the Unitarian School-room, High Street, Swansea, August 27th, 1880.

A letter was read from the President regretting his inability to attend, and enclosing the draft "Report of the Council," with sundry suggested emendations, which were adopted.

The following members having been proposed in accordance with the rules, were declared duly elected as ordinary members.

Dr. Jas. Hector, F.R.S., Director of the Geological Survey of New Zealand.
Mr. Thos. Stewart, of the Glasgow Corporation Water Works.
Mr. Jos. Gill, of Leadhills, Lanarkshire.
Rev. Geo. Gordon, L.L.D., Manse of Birnie, Elgin.

FIFTH ANNUAL GENERAL MEETING.

Held in the Unitarian School-room, High Street, Swansea, August 27th, 1880.

The voting papers previously issued to the members were examined, when it appeared that the following members were elected as office-bearers for the ensuing year (1880-81.)

PRESIDENT.

Professor M. Forster Heddle, F.R.S.E.

VICE-PRESIDENTS.

Rev. Professor Haughton, F.R.S
Rev. Professor Bonney, F.R.S.

COUNCIL.

Professor A. H. Church, M.A.
Mr. T. W. Danby, F.G.S.
Mr. Jas. S. Merry, F.G.S.
Mr. I. F. Walker, F.G.S.

(In place of Messrs. T. Davies, T. M. Hall, M. H. Johnson, and R. Oxland, who retire by rotation.)

TREASURER.

Mr. R. P. Greg, F.G.S.

GENERAL SECRETARY.

Mr. J. H. Collins, F.G.S.

FOREIGN SECRETARY.

Dr. C. Le Neve Foster, F.G.S.

AUDITORS.

Mr. B. Kitto, F.G.S.
Mr. F. W. Rudler, F.G.S.

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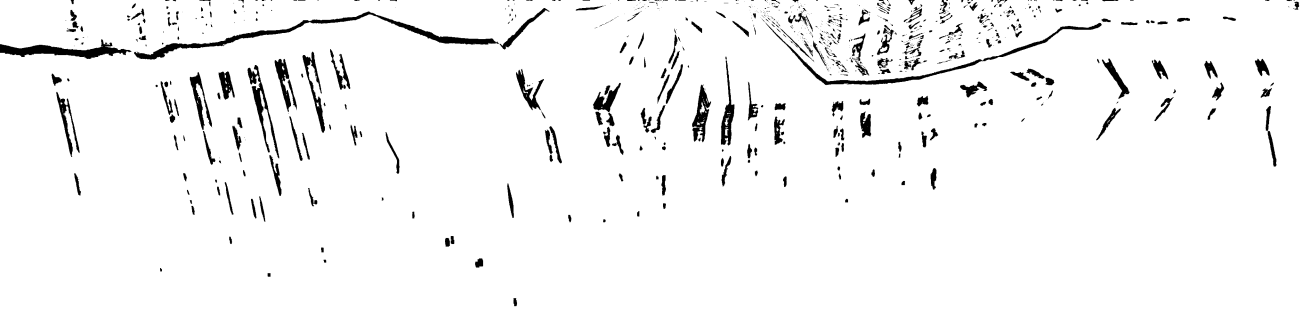

...ers.—M.M.S. (for "Member of the Mineralogical
...M.S. (for "Associate of the Mineralogical Society.")
...apers were read and discussed:—
...ual formula of epidote," by M. l' Abbe Renard.
...rystallized products formed in smelting operations," by
...C.S., communicated by Mr. J. H. Collins.
...urine, hornblende, and schistose rocks of the Porthalla
...H. Collins.
...illustration of their papers were exhibited by Messrs.

LOCAL MEETING.

...ye, *September*, 1880.

...resident in the "Central District of
...Secretary, the Rev. W. W. Peyton;
...south-west coast of Skye being the
...the members accordingly met at Sligican
...along with some strangers who were resi-
...d by coach to Talisker, which is some twelve

...ttle bay of Talisker is buttressed on both sides by mural
...eat height; those upon the south rising in sheet after sheet
...to the altitude of 867 feet. Over these vast walls of
...rock, torrents precipitate their waters from the very verge;
...ing in one spot the edge of a range of basaltic columns.
...tly by the wind which is sweeping upward from the extended
... these waters become dishevelled and broken up into
...which, in the form of a misty veil, are waved hither-
...itherward in perpetually changing folds; becoming for so
...rt of the winds, that it is only the drenched rocks beneath
...for their ultimate fall. Occasionally among the waving
...nbeams play, refracted into prismatic colours of rare brilliancy;
...spectacle marvellous from the rarity of its occurrence, and
...upon the locality a charm which enhances many times the
...hich primarily attaches to it from the plenitude of its mineral

...rty, conducted by the President, who had many years ago
...the locality, proceeded in the earlier part of the day along the
...hore, on account of there being on this side a risk of their being
...d imprisoned by the tide.

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To direct in some measure the researches of the party, Dr. Heddle gave a list of the minerals to be found here. This list included—

Analcime,—*Stilbite*,—*Chabasite* in pure blue crystals, and also of a colour approaching to *acadialite*,—*Mesolite* in downy acicular-crystals, and in feathery-like arrangements.

He also mentioned that the late Mr. James Russel here found the only two specimens of *Epistilbite* which have yet been got in Britain; one of these is now in the British Museum, the other in Dr. Heddle's own collection. The correctness of the locality is proved by the occurrence of acadialite in the matrix of the specimens. Russel also gave this as the locality from which he obtained a specimen which appears to be *scolezite*; and this is also the locality given by him as that which yielded one or two bits of a finely-tinted pale-green *pectolite*, which is associated with large and fine crystals of *apophyllite* in very short prisms. The dealer Doran, however, assigns these to the east shore of Skye, near the so-called Prince Charles' Cave, and the near presence of liassic limestone points to this as being the more probable locality.

With these hints to guide them, the party commenced their explorations, and before rounding the southern horn of the bay, had found *stilbite* in large spheres, resembling the sheafs of Faroe; they also got *analcime*.

Immediately upon rounding the promontory, they found themselves upon the boulder-attrited pediment of two picturesque sea-stacks; and here they found certain of the above recorded minerals in so great a plenty, that the breaking them out of the rock consumed all the time which the advancing tide accorded to them.

The observation of chief moment was the finding of *Heulandite* by Mr. Mackenzie, a gentleman who in a continental University had taken high honours in his mineralogical examination. This Heulandite was in colourless and highly lustrous *b t s P* crystals: this is the second locality in which it has been found in Skye; common as is *stilbite*, *Heulandite* is one of the rarest Scotch zeolites.

In close proximity with this, *stilbite* was found in sheafy or club-head aggregations of crystals of *a b p r*, and in crystals of the form *a b p*.

The observation of most interest, however, was the extraordinary extent to which certain beds of the rock were pervaded with amygdules, which apparently sometimes constituted a third of its mass. In these cases the amygdules contained, in contact with the rock, the pale-blue and the flesh-coloured *Chabasite;* immediately upon these were disposed rosettes of a pale-blue colour, consisting of aggregations of small crystals with the form of *Thomsonite*, or of *faröelite*. The President was disposed to assign them to the former, from his having by analysis proved the occurrence of

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Thomsonite in igneous rocks of this age, which occur at the north end of the island. Superimposed upon these rosettes there lay beautifully delicate interwoven and matted arrangements of downy *mesolite*, or individual crystals of the same, of marvellous tenuity; these, which yielded with perfect elasticity to every breath of wind, shot from side to side of the cavity. *Analcime* in minute brilliant crystals, *n*, also frequently occurred here, for the most part in separate amygdules; a single crystal rarely presenting itself among those of *chabasite*.

Of the last named mineral it was observed that simple rhombohedra (and these were of the acadialite variety) very rarely occurred; twins of the same, somewhat less rarely; this variety being almost always in highly complex twins, which generally presented upwards the crossed face *a*. The blue variety was always in twins, but these were of less complex form. The flesh-coloured crystals were of very much more frequent occurrence, and the two shades never passed into one another.

This goes to support an observation which has been already recorded, that these varieties have a totally different composition. The forms in which the *acadialite* was found were, *p*, *p e*, *p t e*; twins *p t e s*, and the same with 12 small crystals of *p e* inserted upon the *e* planes. The form of the *blue* variety is *p e s* twin.

As regards this, the cliff-foot *south* of the bay, the extent of new information is confined to the discovery of *Heulandite*.

Hurried away by the advancing tide, the party made for the beach north of the Bay, and, in crossing the shores of the cove, observed that its singularly dark sands were composed almost entirely of comminuted dolerite, with about a fourth part of its bulk of clear granules of *olivine*.

Among the smoothed boulders which line the shore, before the rocks of the northern coast line are reached, there were found several which contain imbedded fairly-well developed lozenge-shaped crystals of *olivine* of the form *a d c*. Though these are not over a third of an inch in length, they are probably the best crystals yet noted from Scotland. Striated twins of *labradorite* of a pale-brown, and over an inch in length, rarely occur in a finer-grained rock, in others of these boulders.

Immediately upon reaching the fallen masses which lay upon the shore, the party found abundance of *analcime*, in both large and small crystals; —highly brilliant, colourless, and transparent; as also opaque and muddy-white, rarely bluish. No form other than *n* was seen. It was sometimes associated with superimposed crystals of stilbite *a b r*.

The interesting observation of the occurrence of *bitumen* was next made. It was first seen as a thick coating on the rock, surrounding an empty cavity which was lined with crystals of analcime. The rock in the

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vicinity showed "tears" of the soft, tenaceous, and highly odouriferous substance, which had streamed over its surface for an inch or more. On breaking into the fresh rock, cavities,—sometimes half empty, sometimes full,—were found. In those which were only partially filled, the bitumen occurred with rounded or semi-globular forms, and its passage through the substance of the rock to the surface most directly exposed to the sun's rays, was shown by a dark stain.

It has been said that it was lodged in amygdules which were lined with crystals of analcime; minute filaments of *mesolite* sometimes passed through its substance also; but it occasionally occurred not in amygdules but filling rents in the substance of the rock; and sometimes apparently merely pervading the rock substance itself.

As lignite of liassic age, reduced frequently almost to mineral charcoal, has been found in many parts of Skye, imbedded in trap, there can be little doubt that the action of heat has distilled this bitumen out of the entombed exogenous plants.

Close to this bitumen much capillary mesolite occurs, traversing with its crystals the vacuous centre of analcime amygdules.

A gentleman who accompanied the party got a fine specimen of brown calcite in simple rhombs of the form *f*, these rhombs undoubtedly owe their colour to an impregnation of bitumen.

Mr. Peyton here made, in one block, a double find;—a far from rudely-formed crystal of very dark-green *labradorite*, 9 inches in length, by 5 in breadth. This, being made up of a multiplicity of crystals lying in every direction, went to pieces in the extraction. The small individual crystals are finely striated; it is called *labradorite* at present merely from association.

This assumption of a fairly well-pronounced simple form, by the aggregation of a multitude of small individuals which lie in polar discordance, is of very difficult explanation. It is to be seen in the orthoclase of Pitfechie in Aberdeenshire, and in several other minerals.

The substance which occurred in association with this giant crystal, was *lydian-stone*; it was in imbedded and rounded masses of a dark brownish-green colour; the masses were some inches in dimensions.

The tide did not permit the party to reach a spot where the fallen masses contain fine specimens of *chabasite*, and at which, many years ago, Mr. Dudgeon found probably the finest specimen of *analcime* which Scotland has yet afforded.

The following additions to the minerals of this locality were made:—*ne, labradorite, lydian-stone,* and *bitumen*, none of which had been ucled by Dr. Heddle on his previous visit.

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Retracing their steps, the party observed bands of *plynthite*, of some inches in thickness, zoning the cliff horizontally from bottom to top, at distances of about forty feet, and imparting to it an appearance which was altogether new to most of the members.

It was remarked that, as the specimens obtained were got almost solely from fallen blocks, and as falls were apparently not of altogether rare occurrence, the locality must be almost an exhaustless one. This is hardly a correct inference in either respect. The President did not see much change as regarded the number of fallen blocks since his last visit,—some five and twenty years before; while at the more northerly locality of the Storr, where at that time nearly every stone yielded a specimen, not a bit worth carrying away is now to be had,—the tourist love of *trophies* having swept it bare.

It is mentioned as a detriment to the tourist, and an instruction to the mineralogist, that good specimens are not to be obtained here without the employment of a hammer of at least 14 lbs. weight, while one of 17 lbs. will do twice the work.

List of Books Received from July 1st to September 28th, 1880.

From *Prof. Groth*, Strasburg.
Zeitschrift fur Krystallographie und Mineralogie. iv, 4, 5, 6.

From *Soc. Toscani di Scienze Naturali, Pisa.*
Procesi verbali, p.p. 53-64.

From *Soc. Mineralogique de France, Paris.*
Bull. III. 5.

From *Prof. Tschermak*, Vienna.
Min. und Pet. Mitt. III. 1, 2, 3, 1880.

From *Dr. C. Le Neve Foster, Llandudno.*
Reports of the chief inspectors of Mines for Victoria, 1874-5.
Reports of the Mining Surveyors and Registrars of Victoria, 1875 to March 1880.
Mineral Statistics of Victoria, 1875 to 1879.

From *Prof. Geo. J. Brush*, Newhaven.
On crystallized Danburite from Russell, St. Lawrence Co., New York, by G. J. Brush and E. S. Dana.

From *Prof. T. Rupert Jones*, F.R.S., Surrey.
On the practical advantages of geological knowledge by T. R. J.
On the Fossil Fuels of Italy, by the Chevalier W. Jervis,

From *B. J. Harrington*, B.A., Ph.D., Nova Scotia.
Notes on Chrome Garnet &c., by B. J. H.

From *Prof. Dana*, Newhaven.
American Journal of Science, July to September, 1880.

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From *Reale Comitato Geologico*, Rome.
Bolletino, 5 to 8, 1880.

From *Professor G. Vom. Rath*, Bonn.
Mineralogische mittheilungen, by G.v.R.
Ueber den keutrolith, eine neue Mineral species, by A. Damour and G. Vom Rath.

From *Professor F. J. Wiik*, Helsingfors.
Mineralanalyser utforda på Universitetets kemiska labaratorium &c., by F. J. W.

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EXCERPT MINUTES OF COUNCIL MEETING

Held in the Lecture Theatre of the Museum of Practical Geology, December 23rd, 1880.

Professor M. F. Heddle, F.R.S.E., President, in the chair.

The following gentlemen were duly elected as ordinary members:

James Cunningham, Esq., of Broughty Ferry.
Baxter Gray, Esq., of Broughty Ferry.
H. B. Guppy, Esq., of Falmouth.
R. Shaw Simpson, Esq., of Broughty Ferry.
Stephen Vivian, Esq., of Mwyndy, Llantrissant.

It was Resolved—That Prof. F. J. Wiik, of Helsingfors, be elected a corresponding member.

Resolved—That the estimate of Messrs. W. and A. K. Johnston, for printing the geological map of Sutherland, prepared by Dr. Heddle, be accepted, and that the map be published at one guinea to non-members, and issued as a number of the magazine to members and associates.

Resolved—That the price attached to each yearly issue of the Magazine, or to its parts, be such as at least to equal the yearly subscription of a member of the Society.

GENERAL MEETING.

Held in the Lecture Theatre of the Museum of Practical Geology, December 23rd, 1880.

Professor Heddle, F.R.S.E., President, in the chair.

The following papers were read :—

"On *Tyreeite*," by the President.

"Note on *Gilbertite*," by Mr. J. H. Collins.

"On *Brochantite*," by W. Semmons.

"On a remarkably fine crystal of *Euclase*," by M. Guyot.

"On the action of organic acids on minerals," by Prof. H. C. Bolton.

"Note on artificial *Gay Lussite*," by C. Rammelsberg.

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EXCERPT MINUTES OF COUNCIL MEETING

Held in the Lecture Theatre of the Museum of Practical Geology, February 15th, 1881.

PROF. A. H. CHURCH, F.C.S., in the chair.

The following gentlemen were duly elected as ordinary members.

JAMES BRYANT, Esq., Truro.
T. G. GIBB, Esq, Lewisham.
H. M. PLATNAUER, Esq., the British Museum.
W. TERRILL, Esq., F.C.S., Swansea.
THOMAS WARBURTON, Esq., F.G.S., Canonbury, N.
T. W. WATSON, Esq., Pall Mall, London.

The General Secretary submitted the Audited Balance Sheet for 1880, and the statement of Assets and Liabilities, as appended, (p. xx) which were adopted.

The General Secretary, Mr. J. H. Collins, then resigned his office, as well as that of editor of the magazine, in consequence of his acceptance of a post at the Rio Tinto Mines, in Spain, which necessitated his residence out of England. The Council *resolved* to recommend that Mr. R. H. Scott, be invited to act as General Secretary, *pro tempore.*

It was also Resolved—That Messrs. Church, Hudleston, and Rudler, be requested to act as an Editing Committee, with the President and General Secretary.

It was Resolved—That Mr. Rudler be requested to take charge of the books belonging to the Society, and that any members requiring the use of the same be directed to apply to him.

GENERAL MEETING.

Held in the Lecture Theatre of the Museum of Practical Geology, February 15th, 1881.

MR. R. H. SCOTT, F.R.S., in the chair.

The minutes of the Council Meeting, held on the same day, were read, and it was announced that the Council had accepted the resignation by Mr. J. H. Collins of the post of General Secretary and Editor of the Journal, under the circumstances detailed in the Council Meeting.

was proposed by Mr. Rudler, *and seconded by* Mr. M. Hawkins-ton, and *carried unanimously,*

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"That the thanks of the Mineralogical Society be tendered to Mr. J. H. Collins, for his valuable services as General Secretary, in connexion with the formation and management of the Society."

It was Resolved—That Mr. Scott be requested to act as General Secretary, until the next Anniversary Meeting, and that Professor Church, Mr. Hudleston, and Mr. Rudler, be requested to act as an Editing Committee with the President and General Secretary.

Mr. Scott announced his readiness to discharge the duties proposed to be entrusted to him until the next Anniversary Meeting.

GENERAL MEETING.

Held at the High School, Dundee, March 30th, 1881, in conjunction with a meeting of the Dundee Naturalists' Society.

Professor M. F. Heddle, President, in the chair.

A collection of minerals from Colorado, was exhibited by Mr. G. S. Mackenzie. This collection contained fine specimens of *Microcline and Exansite*; the latter was of so fine a green colour as to lead to the belief that it must contain Cr. Ni. or Cu. None of these, however, had been detected by Mr. Mackenzie, who had analysed it, and was of opinion that the colour was of an organic nature.

Mr. Frank Young of the Naturalists' Society, then submitted a number of minerals collected in the South Sea Islands. Among these the most interesting was a copper mineral, closely resembling the mineral from Pisco, exhibited at a late meeting of the Society, by Mr. W. Semmons, which he had found to be intermediate between Brochantite and Cyanotrichite. Kupfernickel was also among the specimens.

Mr. Irving, the President of the Naturalists' Society, then took the chair, when Dr. Heddle delivered an address "On the scenery of the Northern Counties of Scotland, in connexion with their Geological and Petrological Formation." In this address the varieties of rock sculpture and the hill forms were shown to be dependent on the mutual relationships of the strata—the nature of the rocks themselves, and the diversity of their disintegration under the action of the forces of decay.

The lecture was illustrated by diagrams and drawings of the more remarkable Sutherland hills and the scenery in which they stand, made by Professor Heddle. Considerable interest was taken in a proof copy of the new Geological map of Sutherland which is to be published by the Mineralogical Society.

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Donations of Books to July 11th, 1881.

From *Prof. Dana*, Newhaven.

The American Journal of Science for Nov. and Dec, 1880; and Jan., Feb., March, April, May, and June, 1881.

From the *Academy of Natural Sciences*, Philadelphia.

Proceedings of the Academy, parts I, II, & III. 1880.

From the *Soc. Minéralogique de France.*

Bulletin, Nos. 7 and 8, 1880; and 1 to 6, 1881.

From the *Soc. Géologique de Belgique.*

Annales, tome VI, 1878-9.

From *Prof. Tschermak*, Vienna.

Mineralogische und petrographische Mittheilungen, Neue Folge, Bd. III, Hefte IV. V, VI; and Bd. IV, Heft I.

From *Prof. Groth*, Strasburg.

Zeitschrift für Krystallographie und Mineralogie, Bd. V, Hefte 1, 2, 3 and 4.

From the *Real Comitato Geologico, Italia.*

Bollettino, Nos. 10, 11 and 12, 1880; and No. 1 and 2, 1881.

From the *Società Toscana di Scienze Naturali.*

Processi Verbali, 9th January to 8th May, 1881, and Memorie, IV, fasc. 2.

From the *Administration of Mines of Finland, through M. Furuhjelm, Helsingfors.*

Sheets I. and II. of the Map of the Geological Survey of Finland with description.

From the *Bristol Naturalists' Society*,

Proceedings, new series, vol. III. Part 1, 1879.

From *Dr. C. Le Neve Foster, B. A., F.G.S.*

The Mineral Statistics of Victoria, 1880, and Reports of Mining Surveyors of Victoria for Quarter ending 31st December, 1880.

From *Prof. Liversidge, F.G.S.*, Sydney.

On some New South Wales Minerals.
On the composition of some New South Wales Coals.
On some Minerals from New Caledonia.
On the composition of some Wood enclosed in Basalt.
On Water from Hot Springs, New Britain and Fiji.
On the composition of some Coral Lime-stones from the South Sea Islands.
On the action of Sea-water upon Cast-iron. *All by the donor.*

From *F. R. Mallet, Esq., F.G.S.*, Calcutta.

On Cobaltite and Danaite from the Khetri Mines, Rájputána, with some remarks on Jaipurite (Syepoorite); and on the occurrence of Zinc-ore with barytes in the Kainul district, Madras.
Both by the donor.

From *M. E. Wadsworth, Esq.*, Cambridge, Mass.

On the occurrence of Gold in Maine, and on the Peridotite of Iron Mine Hill, Cumberland, Rhode Island. *By the donor.*

From *Henry Carvell Lewes, Esq.*, Philadelphia.

On Philadelphite. *By the donor.*

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From *Dr. Otto Luedecke*, Halle.

Ueber Reissit; ueber Reinit; Mesolith und Skolezit; Der Glaukophan und Glaukophan-führenden Gesteine der Insel Syra: Ueber die jungen Eruptivgesteine Süd-Thüringens; ueber einen Anorthitbasalt vom Fuji-no-yama in Japan; Krystallographische Beobachtungen. *All by the donor.*

From *Prof. Sandberger*, *Würzburg.*

Zur Naturgeschichte der Rhön; Ueber den Urangehalt von Primitivsilicaten und die daraus enstehenden Uranmineralien; and Ueber der Bildung von Erzgängen. *All by the donor.*

From *M. Emile Bertrand*, Paris.

Etude optique de différents minèraux; and De l'application du Microscope á l'étude de la Mineralogie. *Both by the author.*

From *Prof. Capellini*, Bologna.

Rapports des Commissions Internationales: Congrès Gèologique International, Bologne, 1881.

From *J. H. Collins Esq.*, *F.G.S.* Rio Tinto.

Recent Mineralogical Analyses from the Laboratory of the Royal Institution of Cornwall, *by the donor*; Prof. Abel on Explosives; Report of the Explosives Committee; and A. Davies on Heaves and Faults.

From *Prof. T. G. Bonney*, *M.A.*, *F.R.S.*

The Pre-cambrian Rocks of Charnwood Forest, Parts II and III. *By the donor.*

From *Signor Spezia.*

Sul Calcare albitifero dell 'Argentera.

From the *Sociedad Cientifica Argentina*, *Buenos Ayres.*

Annales for Aug., Sep., and Nov., 1880,

From *Messrs. Brush and Dana.*

Mineral Localities, IV Spodumene, at Branchville, Con., U.S.A. *By the donor.*

From *Dr. James Hector*, *F.R.S.*, *Wellington*, *N.Z.*

Handbook of New Zealand, *by the donor*; and 12th Annual Report of the N.Z. Institute.

From *M. L'Abbe Renard*, *Brussels.*

A number of Mineralogical Papers by L. Sipiocz, E. Ludwig, A. Schrauf, W. Sinida, and Prof. Wartha.

From *M. Delesse*, *Paris.*

Sur les Etudes de Géologie agrinomique aux Etats-Unis. *By the donor.*

From *Prof. Rammelsberg*, *Berlin.*

Ueber einige neue Producte der Sodafabrikation. *By the donor.*

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Mineralogical Society of Great Britain and Ireland.

STATEMENT OF RECEIPTS AND EXPENDITURE TO DECEMBER 31st., 1880.

RECEIPTS.

Dr.	£	s.	d.
By Balance from 1879	41	1	8
,, Subscriptions for 1880	83	3	0
,, ,, Arrears	29	1	0
,, Magazines sold	40	6	0
,, Dividends on Investments	3	7	2
,, Sale of Stock (£60 in 3 p.c.)	58	0	0
	254	18	10

EXPENDITURE.

Cr.	£	s.	d.
To Lake and Lake, for Printing Magazines, &c.	121	12	10
,, Hill and Co., and Brendon for Illustrations	10	12	0
,, Editing Magazine	20	0	0
,, Postage of Magazines	7	9	3
,, Travelling Expenses	25	0	0
,, Carriage of Parcels and General Postage	6	1	8
,, Clerical Work	1	7	0
,, Meeting Expenses	1	19	0
,, General Printing and Stationery	6	12	0
,, Bookbinding	4	9	8
,, Advertisements	3	14	0
,, Insurance of Stock	0	10	0
,, Investments	3	7	2
Balance	42	4	3
	£254	18	10

Examined and found correct February 15th, 1881. (*Signed*) BENEDICT KITTO. F. W. RUDLER.

ASSETS.

	£	s.	d.
Balance	42	4	3
Subscriptions for 1880 (considered good)	50	0	0
Due for Magazines sold	20	0	0
Estimated value of Stock, (⅓rd selling price)	185	0	0
	£297	4	3

LIABILITIES.

	£	s.	d.
Lake and Lake	230	16	6
Sundry bills	3	0	0
Balance	63	7	9
	£297	4	3

(*Signed*) J. H. COLLINS.

TRUST ACCOUNT, December 31st, 1979.

	£	s.	d.
3 per cent. Consols	£142	13	2
June 17th, 1880, sold	60	0	0
	80	13	2
Investment of £3 7s. 2d.	3	8	8
	£84	1	10

(*Signed*) P. DUDGEON, Trustee.

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THE MINERALOGICAL MAGAZINE

AND

JOURNAL

OF THE

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

No. 17. APRIL, 1880. Vol. IV.

I.—*On some Cornish Tin-stones and Tin-capels.*

By J. H. Collins, F.G.S.

First Paper.

THE tin ores ("cassiterite") for which Cornwall has so long been famous occur under the following conditions:—

1. As pebbles, rolled masses, or grains, in stanniferous gravels and sands (stream-tin.)

The detrital tin-ore of Cornwall may be grouped under the following heads:—

a. The tin pebbles and grains of the most ancient elevated quartz gravels, such as those of "Blue Pool," in Crowan, referred to by Mr. Tyack,* and of St Agnes Beacon, mentioned by Messrs. Kitto and Davies.†

b. The pebbles and grains of the "Head" of angular debris—the "overburden" of the china-clay districts. This is often found at elevations not only considerable in themselves, but relatively, as compared with the surrounding country. It differs as a whole from the quartz gravels just referred to, not only in being much less waterworn, but also in being generally much coarser, some of the fragments being very large. It occurs covering killas as well as granite. Grains of tin-ore are often found widely

* See *Trans. Roy. Geol. Soc. Corn.*, Vol. ix. p. 177.

† *Ibid.* p. 196.

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distributed through the subsoil in the neighbourhood of tin veins, even where there is no "head" properly so-called. This may or may not be of the same age.

c. The ancient stanniferous valley gravels. These occur at all elevations up to nearly 700 feet, but always in situations which are relatively low, *i.e.*, in the immediate neighbourhood of ground at a greater elevation. These deposits are now almost entirely worked out,—they have often been described, most completely, however, by the late W. Jory Henwood.*

d. As a constituent of river-gravels and sea beaches now in process of formation. The tin-ore here referred to is generally in fine particles—often angular or sub-angular. Where it is the result of natural processes of denudation, and consequently produced with extreme slowness,—as on some of the isolated beaches near St. Agnes—it is very pure, but where it results from the more rapid operations of the miner, as in the bed and at the mouth of the noted "Red River" which divides the parish of Illogan from Camborne, it is extremely impure from the presence of pyrites, mispickel, wolfram, chalcopyrite, and other more or less readily decomposable minerals. These impurities no doubt existed to some extent in the veins from which all stream-tin appears to have been derived, but have been removed gradually by natural chemical as well as mechanical processes.

2. As the filling of definite fissures traversing granite, slate ("killas") porphyry ("elvan"), and other rocks; usually in a distinctly crystalline condition. The so-called "leaders" of most of the tin lodes of the county are such deposits.

The fissure-deposits properly so-called have been well described by Henwood, Foster, and others.†

3. As the filling of minor joints, fissures, and shrinkage cracks in such rocks, also generally in a crystalline condition. Minute fissures so filled are observable in almost all sections of tin-stones. When such tin-filled joints are numerous, we have the so-called "stockworks" of the county.§

The stockwork deposits are less known than the fissure deposits proper, but they occur in many localities both in granite and killas. Fig. 1, pl. 1 represents a fragment of killas from such a deposit at Minear Downs, near St. Austell.

4. As the cementing material of conglomerates and breccias

* "Observations on the detrital tin-ore of Cornwall." *Journ. Roy. Inst. Corn.*, No. xi., 1874.

† See *Trans. Roy. Geol. Soc. Corn.* Especially Vols. v., viii., and ix.

§ Some of these stockworks are described by Dr. C. Le Neve Foster in the *Quart. Jour. Geol. Soc.*, Aug. 1878, p. 654.

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occupying fissures. Such deposits have been observed at Wheal Fortune, near Marazion; Perran Downs, near St. Hilary; Relistian in Gwinear; and more recently on what is believed to be the same lode as this latter at New Rosewarne Mine in the same parish.

At Relistian rounded pebbles of a dark green chloritic schist several inches across occurred, cemented together by a mixture of oxide of tin, chalcopyrite, and quartz sometimes amorphous, but usually more or less crystallized. A fine specimen of this conglomerate, now in the Museum of the Royal Institution of Cornwall, is represented in fig. 2, pl. 1.

At New Rosewarne Mine Dr. Foster * distinguishes six periods in the formation of the deposit as follows:—

I. Formation of an open crack or fissure into which fragments of the walls fell, and a few pebbles from above.

II. These fragments were cemented together forming a killas-breccia.

III. The crack re-opened; fragments of the already formed breccia fell in from the walls, together with very great quantities of killas and a number of rounded pebbles.

IV. This confused mass of fragments was cemented into a solid mass by having quartz, tin-stone, mispickel, and chlorite deposited around the pieces.

V. Crack re-opened on the south side.

VI. Copper ore was deposited and sent small veins into the already existing tin lode.

Dr. Foster considers that the cementing materials were introduced in the following order or nearly so.

1. Quartz
2. Tinstone
3. Mispickel
4. Chlorite
5. Pearl-spar, calc-spar, chalcedony, iron pyrites and copper ore.

5. As a constituent of ancient breccias occupying fissures, as at Prideaux Wood Mine.

6. As a minor constituent of granite, elvan, schorl-rock, tourmaline-schist, and "capel," mostly in tolerably distinct crystals.

* *Report Miner's Assoc. of Cornwall and Devon*, 1866, p. 26.

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The remarkably rich deposits at East Wheal Lovell * and Rock Hill, † the celebrated "Carbonas" of the St. Ives district.‡ and the numerous apparently isolated nests of tin crystals met with in decomposed granite may be mentioned in this connexion.

7. As pseudomorphic replacements of felspar, schorl, quartz, and occasionally other minerals—in granite, elvan, or capel.

Many of these have been observed at Rock Hill,‖ Belowda Hill,§ and numerous other localities, the crystals being replaced sometimes by cassiterite alone, sometimes by a mixture of cassiterite and schorl.

8. As a pseudomorphic replacement of organic structures.

Fragments of deer's horns impregnated with oxide of tin from the Carnon Valley are now in the Museum of the Royal Geological Society of Cornwall, at Penzance, in the British Museum, and in a private collection at Lostwithiel. These horns will be further referred to hereafter.

Setting aside the stream-tin, which is of course derived from the degradation of pre-existent rocks, the fissure and joint deposits (2 to 5) and the pseudomorphic replacements (7 and 8) are evidently due to stanniferous solutions, and few will doubt that the tin which occurs as a minor rock-constituent (6) is also due to the passage of such solutions through the rock. On this point more will be said hereafter.

The "capel" above referred to is simply an altered band of country, whether granite or slate, occurring in the immediate neighbourhood of most of the fissures which contain oxide of tin. So long as it contains enough tin to pay for working it is regarded as part of the lode by the miners, when it ceases to contain tin or contains so little that it will not pay to work, it is called capel and regarded as "country." It is therefore impossible to separate tin ore from tin capel in any scientific sense.

The workable capel is often many times wider than the original fissure or lode proper. Fine examples of these tin-bearing capels occur at Dolcoath, Tincroft, and other mines near Camborne.¶

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* Foster, *Trans. Roy. Geol. Soc. Corn.* ix. p. 167.

† Collins. "Notes on the Rocks and Goonbarrow Mines." *Rep. Miner's Assoc. of Cornwall and Devon*, 1873, p. 66.

‡ Henwood. *Trans. Roy. Geol. Soc. Corn.*. Vol. v.

‖ Collins, "Notes on the Rocks and Goonbarrow Mines" cited above.

§ Foster, "Notes on Belowda Hill Mine," *Journ. Roy. Inst. Corn.*, xvii., 213.

¶ In a recent paper read to the Geological Society of London, our Foreign Secretary Dr. C. Le Neve Foster has described in considerable detail one of the most important lodes in Cornwall, the so-called "flat-lode" which lies on the south side of Carn Brea Hill near Redruth. This lode has been worked to a great depth in a series of adjoining mines, and for a length of several miles. For a part of that distance it occurs between the granite and killas, but in some places it is bounded by granite, and in others by killas on both sides; the lode although variable in direction (bearing) and slope

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Three distinct modifications of Cassiterite have long been known, and of each there are several varieties which have received distinct names. The three kinds are—

a. *Crystallized* (Diamond Tin, Sparable Tin, Rosin Tin.)

b. *Fibrous and Radiated* (Wood Tin, Toad's Eye Tin, Shot Tin.)

c. *Pseudomorphous* (after felspar, quartz, schorl.)

All three kinds occur in stream-tin, and in well known subterranean deposits.

The crystallization of Cassiterite was long ago worked out with great minuteness by Wm. Phillips, in a memoir presented to the Geological Society and illustrated by no fewer than 235 figures of crystals. Mr. Phillips calls attention to a very important fact which is still as suggestive and almost as puzzling as it was in his time, viz., that certain combinations of forms are characteristic of certain deposits, remarking that "entire veins seem to be productive principally of the same varieties; of this fact he gives several remarkable and striking examples."*

I would also mention an elaborate memoir on the crystallization of Cassiterite, by F. Becke, which appeared in 1877, in Tschermak's Mittheilungen, † in which the author endeavours to shew that three

(underlie) being more nearly in a plane than the actual junction of the two rocks. The actual fissure appears everywhere to have been small, rarely more than two feet wide and often only a few inches—or even a mere joint. The fissure must have been actually open for some time as it is more or less completely filled with a sort of breccia, formed of pieces of the containing rocks cemented together by quartz, oxide of iron, oxide of tin and other minerals. The country is highly silicified, sometimes on one side, but often on both sides of the fissure or lode proper, and thereby converted into what the miners term capel. In some parts, especially near the fissure proper—the capel contains enough tin to pay for working, when it is regarded by the miners as part of the lode and worked as such.

The capel, whether originally granite or killas has now pretty much the same appearance—indeed the only observable difference usually is that the altered killas retains some of its original lamination, while the altered granite has no such lamination. [See fig. 5 pl. iv. Tresavean, and fig. 3, pl. ii. Penhalls.

The following figures from Dr. Foster's paper will shew the importance of this lod from a miner's point of view.

	Tin Stuff. Tons.		Clean Tin Ore. Tons.
Wheal Uny, in 1876 produced ...	17702	.....	349
South Carn Brea	2040	.....	30
West Basset	29144	.....	618
West Wheal Frances	6652	.....	123
South Condurrow	19421	.....	588
Wheal Grenville	8500	.....	138
Total	83459		1846

The average produce was 2¼ per cent. of clean tin ore (black tin). The above was more than one-eighth of the total production of tin ore in Cornwall, in 1876. (See further, Foster on the Great Flat Lode, Quart. Journ. Geol. Soc., Aug. 1878.)

* *Trans. Geol. Soc.* Vol. 2.

† *Min. Mitt.* 1877, p. 244.

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distinct types of form-combination characterise the crystals of Saxony and Bohemia, Cornwall, and Pitkaranda respectively. The author does not, however appear to have seen the elaborate memoir of W. Phillips referred to above.

Crystallized Tin proper is always more or less transparent, thin splinters invariably allowing a large proportion of light to pass. It is occasionally nearly colourless, but generally exhibits various shades of brown, from brownish-yellow to nearly black. Under the microscope in thin sections it always exhibits a peculiar granular appearance somewhat like that observable in olivine. The purest crystals are dark with polarized light and crossed prisms, but generally even well-formed crystals exhibit bright sparkling granules due to minute particles of entangled quartz.*

Cassiterite is distinctly dichroic, but usually very slightly so.†

Large crystals are occasionally found lying loose in the vein as in the case of the fine macles formerly found at Seal-Hole Mine, and the unique curved crystals found at Wheal Fanny; both figured by Phillips in the before-mentioned memoir.

A variety which occurred in the lode at St. Austell Consols a few years since, at a depth of 15 fathoms below the adit, consisted of a mass of amorphous cassiterite covered thickly with minute acicular crystals, the latter evidently a secondary formation.

Wood Tin. This is so called because of the resemblance of its fibrous-radiated structure to that of exogenous wood; it was long supposed to be peculiar to the stanniferous gravels (stream tin), but its occurrence in the lode at Wheal Providence, near St. Columb, in masses of about a pound weight, near the beginning of the present century, was reported to the Royal Geological Society of Cornwall, by Mr. Ashurst Majendie, in the year 1818,‡ since then it has been found at Polberrow Consols, Blue Hills,

* Analyses of crystals of Cassiterite almost invariably reveal the presence of small proportions of silica.

† "The optical properties of tin-stone do not appear to have been investigated since Brewster's time; at least Des Cloizeaux who places tin-stone among the uniaxial and positive substances refers to Brewster (*Ann. des Mines*, 1857, p. 300), as his authority. For investigating the optical properties, a section was used cut at right angles to the principal axis of one of the individuals of a twin crystal from Schlackenwald, whose intercalated twinned lamellæ also permitted an investigation as to dichroism. In the polarizing microscope by white light a dark washed-out cross was seen, without, however any indication of coloured rings, although the plate (or slice) was 1*mm* thick. By using a plate of biaxial mica the cross was resolved into two hyperbolas, the major axes of which were at right angles to the principal optical section of the mica plate.

The twin-lamellæ, which as might be expected (selbstverstandlich), shewed no cross in the polarizing microscope, were examined with Haidinger's dichroiscope and appeared very slightly dichroic. The two images shewed a difference of tint in the brown which was scarcely observable,—one was dark brown with a touch of reddish-brown, the other was slightly duller with a somewhat greenish sheen." F. Becke, in Tschermak's *Min. Mitt.*, 1877.

‡ Trans. Roy. Geol. Soc. Cornwall, Vol. 1, p. 237.

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Penhalls, Wheal Coates, Wheal Coit, and Wheal Trevaunance, all in the parish of St. Agnes; at several mines in Gwinear and Sancreed parishes; and notably in the 162 fathom level at Wheal Vor, in the year 1866.* At this latter mine it occurred in large kidney-shaped masses, associated with crystallized cassiterite and quartz in a part of the Wheal Metal lode six feet wide and worth fully £600 per fathom. The wood-tin occurred mixed up with ordinary crystallized tin-stone together with much chlorite, chalcedony, dolomite, felspar, and pyrites.

A very remarkable occurrence of Wood Tin was met with at Prideaux Wood Mine, many years since in a kind of conglomerate of grains and crystals of quartz cemented together by yellow copper ore and oxide of iron. In this complex mass were embedded fractured segments of globular concretions of wood tin originally from one inch to four inches diameter. These shew a well-marked concentric and radiated structure, the former being indicated by bands of alternate dark and light brown tint. Altogether they much resemble the kind of limonite known as "wood iron." Fine specimens of this conglomerate may be seen in the British Museum.

At the Garth Mine (since known as East Wheal Cock) about two miles west of Penzance, about the year 1827, wood-tin in botryoidal masses and toads-eye tin occurred in great quantity—together with ordinary crystallized tin-stone, quartz, felspar, chlorite and carbonate of iron.†

Wood Tin is so nearly opaque, even when of light colour; and at the same time so brittle that it is extremely difficult to get it transparent enough for examination beneath the microscope. One of its most common modes of occurrence is as a thin opaque fibrous coating on the summits of quartz crystals. ‡ A section of this kind of formation sometimes exhibits a zigzag arrangement of lines somewhat resembling "fortification agate," and might be called "fortification tin." Other forms of Wood Tin are known as "toad's-eye" tin, "pea-tin," and "shot-tin." These consist of small brown spherical masses, in the first case imbedded in quartz or other material of a lighter hue than the oxide itself; and in the second aggregated together with little or no foreign intervening material. F. Becke regards Wood Tin as an extreme form of the well known acicular crystals sometimes spoken of as "Needle Tin." There are however, some rather important physical differences.

* G. M. Henty, Rep. Mincrs. Association of Cornwall and Devon, 1867, p. 55.

† Carne, *Trans. Roy. Geol. Soc., Corn.* Vol. iv. pp. 99-100.

‡ Occasionally these coatings form a kind of cap which may be lifted off at pleasure.

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Pseudomorphous Tin Ore. This occurs at many localities in Cornwall, replacing Orthoclase, Quartz, Schorl, (?) Wood, (?) and Horn.

"Large pseudomorphous crystals of cassiterite after felspar occurred formerly in considerable abundance at Huel Coates, St. Agnes. . . . . Many of the larger crystals presented the curious circumstance of shewing the original felspar replaced by oxide of tin only about half across longitudinally. Similar pseudomorphs have been found at Carn Brecon, St. Mewan, near St. Austell; and also, about ten years ago at Balleswidden, St. Just, by Mr. Rd. Pearce.

The silicate of tin described by Mr. G. Garby is perhaps a pseudomorph after quartz. Some occurred about 1820 (at Wheal Primrose) as an impalpable powder, or compact; yellowish-grey in colour and composed of 53·0 p.c. of oxide of tin, and 46 per cent. of silica. According to Mr. J. Michell, some of the silicate of tin was in hexagonal prisms, much like quartz, but with the summits always wanting."* The writer has one of these prisms in his collection which will be further referred to hereafter.

I have lately been studying the microscopic characters of a considerable number of Cornish tin-stones, and I now propose to bring the results before the Mineralogical Society.

Crystallized Tin-Stones.

a. *Tin in Elvan.*

Tin Ore from Budnick Mine, St. Agnes. This is a compact dark greyish-brown material occurring in irregular veins in a light grey elvan, and also as the cementing substance of brecciated portions of the same elvan; the elvan traverses killas. Under the microscope with half-inch objective, ($\times \frac{66}{1}$,) it appears as in fig. 4, Plate II, and is seen to be composed of cassiterite, quartz, and a fibrous green chloritic mineral. The cassiterite consists generally of well defined yellowish to brownish crystals, often very simple in form, many of them shewing distinct "lines of growth" marked by layers of a darker brown tint, and all possessing the peculiar granular appearance already mentioned as characteristic of cassiterite. A few of the crystals are black with crossed prisms, but most of them are brightly coloured from the presence of minute granules of quartz.

The interspaces between the crystals are mostly filled with quartz, more or less powdered with a greyish to black dusty material, a few fine needles of schorl, and many minute fluid cavities. In places, however, there are patches of the green chloritic mineral, partly fibrous and radiating, partly distinctly crystallized in the form of felspar, of which mineral they are I believe pseudomorphs. This green material is scarcely if at all dichroic. I regard it as one stage in the transformation of felspar into acicular tourmaline.

*ollins, *Handbook to the Mineralogy of Cornwall and Devon*, part ii. p. 25.

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Belowda Hill. This also is an elvan deposit, the tin occurring in nests and veins. The specimens examined show a great deal of tourmaline in large radiated masses. Many of these exhibit bright blue and green tints, with ordinary (unpolarized) light. There are also numerous fine colourless or very pale blue needles of the same mineral, and some radiated groups of a colourless or pale-greenish yellow, flaky or semi-fibrous mineral, which is no doubt Gilbertite.

Two felspars are discoverable, one however being mostly changed into Gilbertite, while the other occurs in moderately large, much-fissured, and only slightly changed crystals.

The cassiterite is mostly present in highly modified "massular"* crystals, but it presents nothing special in its optical characters. A portion of one of the slides is represented in fig. 3, pl. iii, under the one inch power ($\times\frac{28}{1}$)

Parbola. The specimens examined were cut from a dark vein traversing a gray elvan. The sections shew a mass of large crystals of cassiterite closely compacted together. Many of these enclose long slender needles of what appears to be tourmaline, and the few interspaces are filled with a dark brown ferruginous substance. The whole is much fissured, and stained reddish-brown in the neighbourhood of the fissures.

New Rosewarne. In this also the tin occurs as dark veins in a light-coloured elvan. With the one-inch power, the veins are seen to be composed of needles and brush-like groups of tourmalinemingled with large macled crystals of cassiterite.

Tresowes. The specimens examined were cut from a large pebble of "stream tin," found at Tresowes clay works, in Breage. It consists of a mass of large macled "massular" crystals, shewing distinct "lines of growth,"—not unlike the Budnick crystals, but larger and less simple in form. They were probably derived from a vein traversing elvan at Tregoning Hill, on the side of which Tresowes is situated.

Terras, (St. Stephens). This elvan has been rather extensively worked for tin. It is a grayish stone with numerous dark-brown and nearly black patches, which are evidently pseudomorphous fillings of cavities from which felspar has been removed. Most of these are filled with interlacing crystals, or amorphous grains of schorl—some contain both

*Lat. *Massula*,—a little lump. A word seems to be required to denote crystals which are approximately of equal dimensions in all directions. *Massular* will then be analogous to *acicular* and *tabular* as under.

Massular, pretty equal in dimensions.
Acicular, much extended in one direction.
Tabular, much extended in two directions.

"Acicular" crystals are called Prismatic, when the needles are tolerably thick.

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schorl and cassiterite, and a few are wholly filled with crystals and crystalline grains of this latter mineral, mostly "massular".

A piece of this elvan is represented in fig. 3, pl. XI.

A great many other elvans have yielded tin ore in quantity from time to time in Cornwall, as at Castle-an-Dinas, Wheal Jennings,* &c. In all these the cassiterite either occurs as the filling of fissures and veins, or as a replacement of felspar, and always more or less associated with schorl.

At Wheal Jennings sometimes as many as 30 separate "strings" could be counted in the space of one inch.

b. Tin in Granite.

East Wheal Lovell. The slides prepared and examined were from the remarkable tin deposit described by our foreign secretary, Dr. C. Le Neve Foster.† Originally a granite, much of the felspar is changed to a gray, dusty looking material, not dark with crossed prisms, which with a high power ($\times\frac{225}{1}$), seems to consist of minute and imperfectly-formed crystals of Gilbertite, and perhaps a little tourmaline. In places in the neighbourhood of these grayish spots there are very distinct needles of tourmaline, and radiated flakes of Gilbertite. The quartz contains many fluid cavities, and includes a little black opaque mica, together with some irregular crystals and granules of cassiterite, which are of a somewhat darker colour than usual.

Balmynheer. This also is from partially decomposed (kaolinized) granite. It has a basis of quartz which encloses and surrounds bands and nests of small irregular crystals and grains of cassiterite, mingled with minute crystals, grains, and feathery groups of blue and brown tourmaline. Using the half-inch power ($\times\frac{60}{1}$), the quartz appears powdered with grayish dust, but with the one-fifth ($\times\frac{225}{1}$), most of this is resolved into minute needles of tourmaline.

Fleddry (near Bugle, St. Austell). The specimens examined were from a great stanniferous band of only slightly altered granite, which crosses the decomposed granite (Caclazyte or china clay) of the neighbourhood. At Rocks and Great Rocks Mines this is known as the Fleddry lode. The stone is grey in colour, and has a granitic appearance. Under the microscope it is seen to consist chiefly of quartz, having a dusty appearance from the presence of innumerable minute cavities; mingled

* See an excellent description of the mode of occurrence of the cassiterite at Wheal Jennings, from the pen of Mr. Geo. Seymour, Jun. *Trans. Roy. Geol. Soc. Cornwall* IX, 185.

† *Trans. Roy. Geol. Soc., Cornwall*, Vol. IX, p. 167.

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with the quartz, are a little Gilbertite, many dark patches of tourmaline fringed with bluish needles of the same mineral, a few bright yellow and blue patches of tourmaline, and certain dark-gray granular looking masses which appear to replace felspar crystals; with the half-inch power, these latter are seen to be composed of little crystals of cassiterite—mostly rectangular, or nearly so in section. An average sample of the stone taken from the band—which is about 20 ft. wide, and contains very little tin visible to the naked eye—yielded, on analysis, 3½ per cent. of metallic tin.

Wheal Bunny, St. Austell. This is very similar to the stone from the Fleddry lode just described, and it occurs in a lode or band which is probably continuous with it. The bulk of the stone is quartz, in which are many beautiful branches and radiating groups of green tourmaline needles —sometimes surrounding crystals of a yellow, blue, or brown colour, as a fringe. The cassiterite occurs apparently replacing felspar, as in the last example, but is much brighter in colour, and separate crystals are even smaller. No prismatic or acicular crystalsof cassiterite are visible in either of these instances.

West Basset, flat lode. The specimen illustrated in fig. 2, pl. iv. may be taken as a type of the "blue peach" tin-stones of the lodes in the Carn Brea district. Occasionally the tin appears somewhat in the form of broken felspar crystals—in some instances exhibiting a cleavage-structure and form resembling orthoclase. In the section illustrated the cassiterite appears as an irregular band filling a fissure which crosses still older fissures filled with quartz—these latter traversing a matted mass of acicular crystals of tourmaline.

Dolcoath, 314 *fathom level.* This stone is very similar to the last. Here again the veins of quartz cut through the acicular mass of blue tourmaline and are themselves traversed by veins of cassiterite. Fig. 4 pl. iv shews part of one of these veins under the half-inch power, and fig. 3 is intended to illustrate the minute structure of "the blue peach" basis under the one-fifth power ($\frac{225}{1}$). In the fissures there is much acicular schorl. Some of the tin veins are in places as little as $\frac{1}{500}$th of an inch in thickness. Separate grains and crystals are sometimes only $\frac{1}{1000}$th of an inch.

Dolcoath. 324 *fathoms level.* Blue peach tin-stone. This is very similar to the stone just described.

Dolcoath. Sump below the 314 *fathoms level,* 1878. This stone is evidently a breccia, it consists of angular patches of a fine-grained green or bluish material, which is apparently composed in the main of a net-work of fine needles, imbedded in a crystalline mass of cassiterite, which

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exhibits distinct crystals in a few places. A little quartz occupies the interspaces, which are very few—and this encloses many fine needles of tourmaline.

Dolcoath. Very rich stone from about the 260 *fathoms level.* 60 *p. c. metallic tin.* This is a mass of rather large grey crystals—mostly massular, some have a yellowish or brownish centre—there are also frequent yellow stains near the lines of cleavage. Some of the crystals shew very numerous cleavages—mostly however parallel to the principal axis of the crystals. "Lines of growth" are scarcely to be seen in either of my sections (5) of tinstones from this part of the mine. With the cassiterite in all the sections is a little quartz and some fringed crystals of tourmaline. Some of the crystals contain imbedded needles which are probably schorl.

East Caradon, stone raised in 1866. This is a very beautiful stone consisting chiefly of large and rather simple prisms of cassiterite, intermingled with a little quartz and some beautiful dark green hexagonal crystals of a mineral which appears to be tourmaline. Fig. 2, pl. V. represents a portion of one of the slides as seen with the $2\frac{1}{2}$ in. objective ($\times\frac{12}{1}$.)

North Treskerby. This consists of a dark reddish-brown stone, sections of which under the microscope sre seen to consist of light-coloured crystals, mostly prisms, embedded in a deep red, nearly opaque substance, which is mainly, if not exclusively oxide of iron. A few of the prisms are stained with red in spots and patches. The appearance presented when viewed with the one-inch power($\times\frac{28}{1}$) is as shewn in fig. 4, pl. V.

c. Tin in Schorl-rock.

Boscaswell. This is a schorl rock "tinstone," it consists almost entirely of highly modified "massular" crystals of cassiterite mingled with schorl, and forming a firmly compacted mass. It contains, however, many small cavities or "vughs," and these are generally crossed by slender needles of tourmaline as shewn in fig. 5, pl. ii. One slide in my possession has a little striped felspar shewing between the cassiterite crystals; a few minute red garnets are also visible.

Boscaswell Downs. This very beautiful tin-stone is also from schorl rock. It consists of a basis of clear quartz, in which are enclosed many large brilliantly coloured tourmaline crystals, with fringed edges like those described as occurring in the black quartz crystals of Boscaswell Downs.* There are also numerous fine separate needles or small groups of needles of the same mineral sprinkled through the quartz. The quartz basis also encloses some rather large "massular" macles and irregular grains of cassiterite.

* See "On certain Black Quartz Crystals," by J. H. Collins, *Min. Mag.*, Vol. I, p. 115.

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Rock Hill. This stone is from the remarkable mass of stanniferous schorl rock described by me in the Mineralogical Magazine, in 1876.* In some parts the rock is composed largely of quartz, in others it chiefly consists of schorl, but everywhere there is a little tin. Fig. 1, pl. iv. represents a thin section of a dark bluish mass from this deposit, under the half-inch power ($\times \frac{66}{1}$). When thus examined it is seen to be composed in the main of an agglomerated net-work of very fine acicular crystals of blue tourmaline, in which are imbedded radiated groups of much larger crystals of brown tourmaline, and a few small crystals of cassiterite exhibiting the characteristic granular appearance.

d. Tin in Killas.

Wheal Vor, 160 *fathom level.* This is a killas "tin-stone," it is, however, very similar to the Budnick specimen, but the crystals of cassiterite are less distinctly prismatic, generally somewhat more highly modified, frequently fractured, and often macled. Fig. 1, pl. iii. shews one of these macles drawn with the camera lucida under the half-inch power ($\times \frac{66}{1}$).

The quartz of this stone contains many minute fluid cavities and a green fibrous chloritic mineral, similar to that occurring in the Budnick specimens.

Tretoil. This is also a killas tin-stone. It consists of a *melange* of crystals of cassiterite, mostly short prisms, with a very little of a dark interstitial mineral—probably oxide of iron—and a few cavities which seem to have been originally felspar crystals, but are now occupied by a semi-fibrous greenish, grayish, or yellowish mineral. Fig. 4, pl. V, represents part of a slide of this stone as seen with the one-inch objective.

With polarized light these crystals shew brighter colours than usual. No quartz is visible in the stone.

Part of the specimen was analysed and yielded 92 p.c. of oxide of tin.

Wheal Vor, 140 *fathom level.* This is a specimen of a kind of ore which was worked very largely at Wheal Vor, a few years since. It consists of alternate bands of dark grey slate, and of quartz filled with crystals of cassiterite. Fig. 2, pl. iii. represents part of a thin section magnified, shewing the dark slaty bands alternating with the lighter bands of quartz, and these latter interlaminated with oxide of tin, sometimes in irregular forms, but mostly in crystals more or less highly modified. Fig. 4, pl. iii, represents a part of the same section more highly magnified ($\frac{150}{1}$.). The quartz seems to have crystallized between

* On the occurrence of Achroite at Rock Hill. *Min. Mag.*, Vol. I., p. 55

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the laminæ of the slate so as to extend them, and the tin oxide has then been deposited in its cracks and cavities.

With the one-fifth objective ($\times\frac{225}{1}$), many fine needles of tourmaline are visible, which seem to lie mostly with their long axes in the directions of the laminæ, and to follow them in their bends around certain dark shapeless opaque knots, which are probably amorphous tourmaline. An attempt to represent this appearance is made in fig. 5, pl. iii.

New Fowey. These specimens are from a lode traversing killas and situated a little to the north of the great Fowey Consols lodes; it has only been worked a few fathoms deep. In this specimen with the quarter-inch power ($\times\frac{150}{1}$), the cassiterite is seen to consist of small highly-modified crystals mingled with chlorite, some of which occurs in beautiful rams-horn groups; the whole imbedded in a basis of quartz as shewn in fig. 2, pl. ii.

Part of this specimen was analysed and yielded 22 p.c. of oxide of tin.

Penhalls. The specimens examined consisted of a dark grey very siliceous killas. Under the microscope the appearance did not materially differ from the Penhalls capel, hereafter to be described, except that there were veins and patches of tin visible.

Penhalls "Toad's eye" Tin. Much of the toad's eye tin observed in different mines—as at the Garth Mine near Penzance, consists of wood-tin, and will be described in a future paper. Much wood-tin occurs too at Penhalls Mine, but the specimen of "toads eye" examined from here, which was kindly furnished by Dr. Le Neve Foster, consists chiefly of ordinary crystallized tin, arranged in a somewhat peculiar manner.

To the unaided eye the specimen presents the appearance represented in the fig. 1, pl. V. A thin cross-section under the two inch power ($\times\frac{16}{1}$) shows a group of cross-sections of rectangular prisms, imbedded in and surrounded by quartz. This group is surrounded at a little distance by an incomplete circle of crystals having a slightly radiating structure, and exhibiting nearly concentric lines of growth as shewn in fig. 3, pl. V. A few angular dark patches which also have a somewhat circular arrangement are apparently interspaces between quartz crystals; some of them are seen to contain many minute needles of tourmaline when viewed with high powers. Others look like very dark wood tin.

The whole arrangement looks as if it had arisen as follows:—

a. Formation of bundles of prisms of cassiterite in a quartz magma.

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b. Deposition of quartz in more or less distinct prisms around the centres so formed.

c. Deposition of cassiterite and tourmaline irregularly on the outside of the quartz groups, part only being crystallized.

d. Deposition of quartz around the whole compound mass.

Wheal Fortune, Breage. The specimen examined consisted of a dark greyish-brown killas spotted and banded with white quartz, and having light yellowish-gray macled crystals of cassiterite in its joints varying from $\frac{1}{4}$th to $\frac{1}{12}$th of an inch across, and mingled with a little Gilbertite.

Thin sections of the killas near the joints were made, and in these the quartz was seen to be as usual full of minute cavities, giving it a gray dusty appearance. It also contained very large numbers of tourmaline needles, blue near the tin crystals of the joint, but elsewhere brown, and arranged in a somewhat banded manner, the joints cutting the bands nearly at right angles. The whole may be regarded as a stanniferous tourmaline-schist.

Roche Consols. This also is a highly stanniferous tourmaline-schist, the basis of which is mainly cassiterite instead of quartz as is usual. It is much more stanniferous than the last as the tin seems to permeate the whole rock, instead of being mainly confined to the joints.

Wheal Primrose, St. Agnes. The specimen from which my sections were cut was an old one, the mine having been closed for many years. It is a compact grayish stone to the naked eye, not unlike a stanniferous sandstone. In a thin section it is seen to consist of a mass of light-colored quartz full of minute needles of dark-brown cassiterite, often pointed at each end. A good many brown patches and grains of oxide of iron are visible, and also some patches of what looks like tourmaline

e. Tin Breccias

Reference has already been made to the occurrence of cassiterite as the material filling fissures, &c., in various kinds of rock. The specimens now to be described probably differ nothing in principle from these, but being on a much larger scale, it may be convenient to place them here under a separate heading.

Relistian and New Rosewarne. The tin conglomerates of these mines have already been described (page 3).

Wheal Lucy. This mine was worked a few years since to a very moderate depth. The tin deposits were very irregular, much of the tinstone consisted of a breccia composed of a peculiar soft brownish material, which looked like decomposed greenstone, cemented together

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with cassiterite, often in large crystals, and a little quartz. A specimen of this breccia is represented in fig. 3, pl. i, drawn to the natural size.

In thin sections under the microscope some of the included fragments exhibit a structure which might very well belong to a basaltic rock which had undergone much decomposition.

Wheal Uny. Compact Tin-stone. This is a very peculiar tin-stone. Viewed in the mass it looks like an alternation of bands of dark "blue-peach," and of a paler grayish-brown material, both extremely fine-grained and very hard. Under the microscope, in thin slices, it looks like a breccia, in which ordinary "blue-peach" plays the part of the cementing material, and encloses angular fragments of a peculiar brownish-gray granular material, which certainly contains tin, from the known richness of the stone, but is optically quite unlike ordinary crystallized cassiterite. The whole mass has been fissured across, and the fissures filled up subsequently with quartz, and, in one specimen, some very light coloured crystals of cassiterite of the ordinary kind. In the neighbourhood of this there are distinct needles of schorl; elsewhere these are almost entirely absent, the blue-peach being mostly made up of the greenish or bluish chloritic material.

Needles of the tourmaline project into some of the quartz masses, and these latter as well as the quartz of the veins are full of minute fluid cavities.

TIN CAPELS.

As already stated, there is no real geological or petrological distinction between *tin-stones* and *tin-capels*—a capel being merely a tin-stone which does not contain enough tin to pay for working. As the average produce of the Cornish tin-stones is but little over 2 per cent. of tin-oxide, and as many are worked with less than 1 per cent., it will be seen that the distinction made by practical men rests entirely upon considerations of economical working, which vary with the locality and the surrounding conditions. Thus the 'capel' of one mine may be the 'tin-stone' of another.

To the unaided eye capels appear in three principal forms, which may be termed *granitic*, *schistose*, and *compact* respectively. The latter is essentially a deposit of amorphous or crypto-crystalline quartz, which may or may not enclose particles of foreign bodies; it is not usually of much importance, nor does it occur to any very great extent in connexion with the Cornish tin ores.

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The granitic and schistose capels on the contrary are of the highest importance, and are usually readily enough distinguishable from each other, although they no doubt pass into each other at times. Both are very highly altered rocks, which have been altered by precisely the same chemical agencies. Both are characterised in general by the presence of much tourmaline in some form or other, and the types of their extreme modifications are 'schorl-rock' or 'schorlyte,' and 'tourmaline-schist.' Each consists essentially of quartz and tourmaline, in the first arranged irregularly as in granite, in the second in approximately parallel bands, due no doubt to the original lamination of the schist from which it has been derived. Occasionally both may be seen in one stone as in the specimen from Wheal Burn, illustrated in Plate VI.

Both these important rocks are found in great abundance near the junctions of granite and killas—and I believe nowhere else; rarely indeed are they found more than a mile from the actual junction except of course as surface or subsoil fragments, or as transported materials in valley gravels, and occasionally in so-called raised beaches.*

a. Granitic Capels.

South Condurrow, flat lode, "grey back," or "black-granite." In mass this is very dark bluish gray, evidently an altered granite, the felspar changed to quartz, and the mica to the mixture of chloritic mineral and tourmaline already so often referred to. There are many tourmaline needles in the fissures, and a few irregular grains of tin—some not more than $\frac{1}{3000}$th of an inch across. With the one-fifth objective and a good light, many little yellow grains appear, which may perhaps be tin. Some of these are scarcely more than $\frac{1}{30000}$th of an inch across.

Tresavean. This is a good example of the "blue peach" slightly stanniferous capels, its shadowy granitic structure is shewn in fig. 5, pl. iv. under the half-inch power ($\frac{20}{1}$). Some of the patches of quartz have much the form of felspar crystals, and I believe they were once felspar.

* The quartz of veinstones is usually more or less crystalline, contains numerous gas and fluid cavities, and encloses ores of tin, copper, zinc, and other metals. Capels are most frequently composed of a quartzose base through which crystals of schorl are very thickly disseminated, either in the form of spheroidal aggregations radiating from various centres or as acicular crystals crossing one another in all directions. Sometimes, particularly when they occur in slates, capels are mixtures of quartz and chlorite; in others both chlorite and tourmaline are present. They also often contain innumerable small fragments of the country rock, and are traversed by narrow strings of quartz into which project hair-like crystals of schorl, which are generally attached to the sides of the enclosing fissure. Phillips, *Quart. Journ. Geol. Soc.*, Aug. 1875, p. 341.

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West Basset flat lode, 114 fathom level. This is a good deal like the Tresavean stone; the "blue-peach" basis is mostly, however, grayish when viewed with a high power, and it seems to consist chiefly of a flaky mineral penetrated in all directions with minute needles of blue tourmaline. A few pale green patches are present, which are perhaps chlorite. No tin is visible in this stone, except perhaps in patches, in one little vein less than $\frac{1}{500}$th of an inch in thickness, which small as it is, is in one place distinctly "heaved" at an oblique angle by a still finer one not more than one-tenth its breadth. The brown patches look somewhat like wood tin, and are distinctly fibrous under high powers; they are however still more like a brown tourmaline.

Another specimen from this locality shews a little tin and a few brown spots, which are probably peroxide of iron.

Carn Brea. This also is a 'blue-peach' capel. Under the microscope it is seen to be composed mainly of quartz, together with patches of the bluish felted material, a few distinct blue and yellow crystals of tourmaline, and a few grains of tin, the whole exhibiting a shadowy granitic structure.

There can be little doubt that the four specimens last described, which are types of at least one half of the tin stones at present worked in Cornwall, represent granite rock altered *en-masse*, the felspar mostly changed to quartz, the mica to chlorite and schorl; the whole much fissured and filled up at different periods with quartz and cassiterite. The matted mass of "blue peach" frequently encloses irregular angular portions of quartz, the remains of the quartz of the original granite, together with other quartz masses of a more regular form, and apparently pseudomorphous after felspar.

b. Schistose Capels.

Penhalls. This is a good example of an altered killas capel—really a variety of tourmaline schist—in which the alteration has not proceeded so far as to obliterate the original laminated structure. Fig. 3, pl. ii. is drawn as seen under the two-inch objective ($\times \frac{16}{1}$). The rock consists mainly of quartz, but is rendered somewhat laminated by a series of fine bands of amorphous tourmaline. It has been fissured and repaired in several directions and at several distinct times. The whole is crossed by a fissure which is mainly filled with quartz, but carries on its walls an irregular band of a green chloritic mineral, resembling that already described as occurring in the specimens from Budnick and Wheal Vor. A small

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nest of cassiterite is shewn at one place. With the one-fifth power ($\times\frac{225}{1}$,) as in fig. 1, pl. ii. the green mineral is seen to be chlorite, sometimes in approximately hexagonal crystals, but more usually in irregularly radiated bundles of plates presenting a fibrous appearance and in the form of felspar crystals. In one or two places the rams-horn groups so common in the New Fowey tin-stone may be seen. The fibrous chloritic substance and the amorphous bands of tourmaline appear everywhere to be passing into acicular needles of tourmaline, which seems to be the final product of the cycle of changes.

Wheal Vor. This is a very hard capel, very similar to the last, only the needles of tourmaline are larger. There are a few small crystals and grains which look like cassiterite, but I am not certain about them.

New Consols Mine. The general structure of this capel is like that of Penhalls, but it contains no chloritic mineral. Instead of this there are many opaque patches and grains of a grey mineral, which shines with a greyish metallic lustre when viewed as an opaque object. As the stone contains arsenic, this substance is probably mispickel.

In the fissures there are a good many acicular crystals of tourmaline, but no tin is visible in the sections examined, although the capel yielded a little tin by treatment on a large scale.

Cusgarne Downs (*Tourmaline Schist.*) This is part of one of the striped surface stones from the junction of the granite and killas which are so abundant in most of the tin producing districts of Cornwall. Like the Penhalls specimens it consists of alternate layers or bands of quartz and tourmaline. The tourmaline here is mostly brown, and occurs in short, rather broad prisms, formed around some opaque substance, which has probably supplied the ferruginous constituent of the tourmaline. The quartz encloses many minute prisms and grains of the same mineral, and a few approximately rectangular brown crystals which may be cassiterite. This may be regarded as a typical specimen of the Cornish tourmaline schist. It contains about 150 distinct bands or layers to the inch.

Park of Mines. (Fig. 4, pl. VI.) This is an example of tourmaline schist, from the immediate neighbourhood of one of the richest deposits of tin ever discovered in Cornwall,* but it has many characters in common with the capel just described and also with one of the Wheal Vor stones. As indicated by the figure it is composed of alternate layers of schist, many hundreds to the inch—the dark layers chiefly tourmaline and the

* See "A Deposit of tin in the Park of Mines," by Dr. C. Le Neve Foster.—*Report Miners' Assoc. Cornwall and Devon*, 1876.

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light ones chiefly quartz. Most of the tourmaline here is dark-grey to nearly black and opaque, and in irregular masses, but a few fine needles project into the quartz and here and there a minute grain of tin oxide is discernible.

The foregoing descriptions relate to examples of most of the ordinary tin-stones of Cornwall which contain crystallized cassiterite. In a future paper I propose to deal with the numerous varieties of wood-tin, and to discuss the origin of the Cornish tin-pseudomorphs and tin deposits generally.

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II.—*The Geognosy and Mineralogy of Scotland.*

By Professor Heddle.

COUNTY OF CAITHNESS.

"A monotony of external configuration affords" says Geikie, "a good indication of the sameness of the geology"; and a country which is devoid of scenic interest, however well it may in a few cases fill the pockets of the metallurgist, will assuredly never satisfy the cravings of the scientific mineralogist.

A land of diverse formations, gashed by rivers, gouged by glaciers, cleft by faults, and hitched about by slips,—with its mountains never of the same mind as regards the fashion of their contours, tossed hither and thither as if they had been kicking about in chaos,—in such a land, he who would learn from the pages of nature may rest assured that he has much to read.

Caithness stands apart from all the counties of Scotland,—pre-eminent in monotony, pre-eminent in ugliness, pre-eminent in dearth of minerals.

A land of flatness,—flags, and fossil-fishes,—the glories of colour and lustre and form are unknown to it: metamorphism, and pseudomorphism and isomorphism, and homœomorphism are words not to be found in its dictionary: it can hardly add one tittle to the records of the past, has no tale to tell of how the old things became new. On its dismal dyke-lined roads the most stalwart walker would grow weary, the hill-man find his occupation gone, for there is little here to climb.

There are some three fairly well shaped hills it is true, but these have huddled themselves in a far off corner in repugnance. Some fairly good cliffs there are, but these, in the singularly rectilinear coasts, impress one with the feeling that they have turned their faces from the land in shame.

An Old Red Sandstone country, which has concentrated all the flatter features of Orkney, with none of its interest, and but few of its minerals.

A patch of quartzite in the south—and nobody seems to understand how it got there, or what it belongs to; and a portion of an igneous rock of the adjoining county, which had thrust itself into the land, but stopped short chilled by the dismal swamp which lay before it.

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Its two chief headlands have been mantled, and rendered somewhat more respectable by the upper sandstones of Hoy; but about the best that can be said of the county as a whole is, that its geology is *flags*, and its history is *fishes*.

Minerals.

The record is very brief.

In his paper on the Mineralogy of Sutherland, Cunningham writes,—"The solitary instance to which I allude is the discovery of *fluor spar* in the Ord of Caithness, a mountain forming the northern extremity of a granitic band, which stretches along a considerable portion of the east coast of the county. The point where this mineral was detected is in some precipitous cliffs overhanging the burn of Ousdale (Ausdale), and near a rocky ledge, over which the stream falls, at a short distance from its confluence with the sea.

The fluor occurs in the granite in two distinct modes, viz., as imbedded concretions, and as mere threads. The former I have never found larger than a small pea; and the latter, though they may have a length of several inches, were in no case perceived to have a greater breadth than a quarter of an inch. Its colour is the imperial purple of Werner's nomenclature, and the usual cuboidal crystalline form is in some instances distinctly developed."

To Dr. Joass, of Golspie, I am indebted for specimens of lamellar *baryte*, from Thrumster, about six miles south of Wick; and to the same gentleman and A. H. Gillieson, Esq., for *limonite*, with imbedded *rock crystal* from the banks of the Isald burn, near Achavarasdale in Reay. The limonite was granular and very siliceous; Dr. Joass failed, after much trouble, in procuring me specimens pure enough for analysis, though he believes that it is sometimes fibrous.

Upon the north shore, near John o'Groats House, *augite* occurs. It was found and sent to me for analysis by Professor Geikie, who on the 2nd November, 1879, wrote as follows:—

"You should receive to-morrow a parcel containing the pieces of the John o'Groat's augite.

I have not time to send you full particulars at present. It occurs in rough, rounded, and broken lumps, imbedded in the coarse agglomerate of a volcanic neck, belonging to the Upper Old Red Sandstone time.

I have had it sliced, and have examined it microscopically. It is not in the least dichroic, and has none of the other features of hornblende.

I have no doubt it is augite. Some of the rough granular pieces suggested, at first, olivine to me. But I found this granular character to be exceptional, and the mineral is fusible, and with hardness equal to 5·5.

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It is by far the most interesting volcanic augite I am acquainted with."

On the 4th December, he writes:—

"The specimen I send you is one of a number of pieces of what seems to me to be a form of augite, which I have found in the most northerly volcanic rock on the Mainland of Scotland.

This occurs on the shore, half a mile to the east of John o'Groat's House.

While the whole of that part of Caithness lies upon the so-called "Caithness flagstones" of the Old Red Sandstone, the coast at the locality in question affords an admirable section of the red sandstones, with blue and grey flags and shales (sometimes with well preserved ichthyolites), which form the highest visible portion of the Caithness flagstones.

No igneous rocks of any kind are interbedded among these strata or in any other part of Caithness.

It was therefore with the utmost surprise that, when examining the coast line in the year 1874, in company with my colleague in the Geological Survey, Mr. B. N. Peach, I came upon a well marked volcanic "neck" or pipe, which had been drilled through the John o'Groat's sandstones.

I have no doubt that this neck marks the chimney of one of the Upper Old Red Sandstone Volcanoes.

I again visited Caithness last summer, accompanied by another survey colleague, Mr. John Horne, and made further notes about this interesting locality.

The neck is irregularly oval in shape; the diameter, on this edge truncated by the sandy beach, being about 300 feet. The sandstone round it is somewhat hardened and jointed, as may usually be observed in similar cases. The whole space of the neck is filled up with a coarse tumultuous agglomerate of a dirty green colour, which makes it stand out in strong contrast to the surrounding red sandstones. The paste of this rock is a granular tuff, formed evidently of comminuted diabase.

The blocks imbedded in it are angular, subangular, and rounded, of all sizes up to masses of a yard or more in diameter. I observed among them pieces of diabase (these form the great majority), no sandstone, grey flagstone, gneiss, and abundant fragments of the augite which I send you.

Some of the diabase blocks were of great size, but, as veins of a similar rock traverse the neck, it was not always possible to tell which were parts of veins, and which were really detached blocks. The augite fragments are all rounded, as if they had undergone considerable trituration before

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they came to rest. Here and there they show a rough cleavage-face, which may have been produced by their striking against another ejected block. They vary in size from mere seed-like grains, up to blocks at least eight or nine inches in diameter.

No sign of fusion, or even of good baking, was to be seen in the bits of imbedded sandstone in the agglomerate.

I should add that I did not observe any minerals associated with the augite, except such as had resulted from the alteration of the tuff.

There cannot be the least doubt that the fragments of augite are true ejected blocks, and did not originate in the matrix where we found them.

They are by no means the only examples to be met with among the Scottish tuffs, though they are very much larger than any I have before observed. Next to these in size, were some which I found in a neck on the shore to the south of Fairlie in Ayrshire, belonging to the Lower Carboniferous volcanoes."

Upon examination, I found these specimens to be of a dark bottle-green colour, and a high vitreous lustre; their specific gravity was 3·36.

They yielded,

Silica	46·076
Alumina	11·391
Ferrous Oxide	7·921
Manganous Oxide	·461
Lime	16·067
Magnesia	15·653
Potash	·818
Soda	1·058
Water	·38
	99·825

These are masses therefore of an *augitic-glass*, somewhat similar to, but neither so much vitrified or flawed as specimens which I had myself previously discovered and analysed from Elie in Fifeshire, and the Giant's Causeway in Ireland.

It will be observed that Geikie remarks on the granular pieces suggesting olivine to him: which mineral the Elie specimens were considered by the writer to be, until their analysis established the occurrence of augite in this peculiar allomorphic condition.

The resemblance to olivine is, in the John o'Groat specimens, by no means—even in the most granular portions—so striking as in those already mentioned; while some portions of the specimens show the cleavages and fractures of unchanged augite.

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This fact of the specimens presenting a changed and an unchanged portion,—having been caught or arrested in the middle of the process of change,—renders them certainly far more interesting, from the amount of information they convey, than those in which the glassy condition is perfect.

"Rough, rounded, and broken lumps," —the words well describe them as hand specimens. We will consider these features in a different order, that we may see what they teach.

"Broken";—"rough" because broken; and "rounded,"—that is partially rounded, or they would not still be rough,—rounded on account of some attriting action which operated after they had been broken.

Evidence of their having been broken,—i.e. that they are the fragments of a larger mass. Mere roughness could not prove this: the steam holes of igneous rocks though usually more or less spherical, and presenting rounded or curved outlines, are not invariably so; so that a mineral which ultimately plugged these, through endosmose, would, in the taking a cast of a rough cavity, assume a rough outline; while again, if the augite, after thorough fusion, was, on the abstraction of the heat, to assume the solid state, while the rock matrix was still in a plastic condition, it might form a confusedly crystalline mass with rough surfaces. That the roughness of outline is not here to be so explained, but is really due to irregularity of fracture, is shown *first* by large and fairly brilliant cleavages of the augite abutting against what have been the sides of the masses, as shown by a thin investing layer of calcite, and skin of chlorophæite(?)—and abutting at such an angle to these sides as could be formed neither by a crystalline arrangement which radiated from the sides of a cavity, nor by one radiating from the centre of the mass. The above cleavages, *secondly*, are of such size as show that they must have originally belonged to masses of much greater dimensions than those in which they are now found.

And, *thirdly*, the rough fractured sides occasionally exhibit, as also do internal fractures, portions of crystals of a size much too great to have been formed during the solidification of masses so small as these.

As regards the rounding, it amounts in general to little more than the abrasion of the protruding cleavage-angles, not to the giving a rounded outline to the general mass. The surfaces are now covered with a thin coating of calcite: the nature of the abrasions cannot be seen; it certainly has not been of the continuous nature of wave battering, or river grinding, or sand blowing.

As regards internal structure, there is here the same confused and hackly fissuring which I described in the Elie mineral, the fissures being, however,

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narrower, and the whole mass more coherent; these fissures are, for the most part, filled with saponite (?) the probable result of incipient change, and rarely with calcite.

The recent fractures are, like those of the Elie specimens, conchoidal; though here and there true cleavages in broad sheets cross the conchoidal fractures, and even lie in directions non-accordant with the cleavages of the less altered portions of the mass; these latter having been, in fact, posterior in formation to the vitrifaction. The conchoidal fractures exhibit a perfect bottle-glass appearance, very similar to that of augite melted in a crucible. Close inspection with a lens, however, shows on the crystalline surfaces a cupped appearance, quite similar, though not so minute as that which, in decomposed glass, was shown by Sir David Brewster to be the cause of the iridescent colouring. Closer inspection still demonstrates that these cup-shaped hollows had been the receptacles of little spheroids of felspar, which may be seen arranged in layers in portions of the mass of the stone. I call the spheroids *felspar* merely from the lustre of their cleavages, and from the presence of alkalies, as shown by a partial analysis.

Two questions at once connect themselves with these "rough, rounded, and broken lumps," which helped to choke up a former volcanic orifice.

The first—*whence came they, or what were they broken from?*

The second—*do they, in themselves, give us any information as to the amount of heat to which they had been subjected in the process of their vitrification?*

These two question may resolve themselves into the more general one—*is there any likelihood that we may be able*, by their recognition as components of a well known stratum, or by the amount of alteration which has been effected upon them by heat—*in any measure to arrive at an estimate of the depth at which the volcanic turmoil originated.*

Such a question is too wide a one to be entered upon in its entirety here; but although a consideration of it, in the two directions indicated above, may lead us but a small extent to any definite answer, yet to that small extent it unquestionably must lead us.

All *fragments* must have been brought by an outflow from beneath the parent rock from which the fragments were torn; the amount of change is the register of *the highest degree of the heat* which was the active agent of the change.

Asking ourselves in this instance, whence came these lumps of augite, we are able to reply unhesitatingly from no part of the Old Red: no formation, not even the chalk could have less claim *in itself* to an augitic mineral.

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Inferior to the Old Red we have in this part of Scotland, gneissic and flaggy schists, thrown into wavy folds where they cross the breadth of Sutherland; these, where they underlie the sandstones here, are probably similarly crumpled, and have no great downward trend. Beneath these fractured and folded rocks again, we come upon the gently inclined beds of a highly silicious conglomerate; which beds vary among themselves not at all in the nature of their constituents, but only in the amount of attrition to which their component pebbles have been subjected; they are altogether destitute throughout of vein, or seam, or cavity, within which a crystalline or cleavable mineral had space or time to arrange its atoms.

Going lower still, we may walk for miles across the upturned edges of a rock, the beds of which strike vertically downwards with such an unvarying determination of purpose, that we are impressed with the whimsical fancy that if we ever again meet with them it must be when they come out at the other side.

After many traverses of the formations mentioned, my experience does not enable me to indicate any one spot or bed which could afford an augite the representative of this.

The Shinness limestone locality shows, throughout its great abundance of the mineral, no trace of such a variety.

I know of but one isolated occurrence of augite in the midst of the vast abundance of hornblende in the lower gneiss.

The well known conversion of hornblende into augite by heat may possibly account for its occurrence; but in this case a *double action* is required,—the first, that by means of which the transmutation was affected, resulting in the production of the broadly cleavable masess. The second, that which produced the final vitrification of these masses. Of any such double action we have here evidence only of the feebler,—the vitrifying.

The second part of our query, namely, the topmost limit of the heat to which the augitic lumps had been subjected, is more easily answered, seeing that a near approximation may be arrived at by direct experiment.

Many years ago I had an opportunity of determining the temperature to which fragments of different members of the lower Coal Measures had been subjected, when caught up among the ashes which form the small volcanic cones and necks around the shores of Fife.

In the shore sections of the wave-worn bosses of tufa which stud the coast near Kinkell, much fragmentary matter of various descriptions is to be seen promiscuously imbedded, and characteristically and instructively altered. The bituminous shales have lost all their illuminants; and, of

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organic matter, retain only the blackening stain of sparsely distributed carbonaceous particles.

The encrinal limestone has become granular and crystalline.

The included freestone masses present themselves as a quartzite, with firmly agglutinated grains, splintery fracture, elastic resilience, and sonorous ring. Shivery masses of carbonaceous or "black chalk" clay show every stage of a passage into Lydian stone; while volcanic bombs of the latter, perfect in the transmutation, lie impacted in the encircling volcanic mud, with surfaces which exhibit rounding and abrasion.

We have here abundance of material to work upon, in estimating the quantum of the energy expended in the production of these changes.

Close observation of the altered calcareous fragments shows most clearly that the period of time, during which they had been subjected to the heat, had been of but short continuance; for while it will be found that the smaller of these fragments are, to their very centres, converted into a crystalline mass, reflecting light from innumerable facettes; the larger exhibit the change only to a certain depth; the interior presenting itself as an impalpable calcareous basis, studded occasionally with joints of the encrinal stems.

More than once I have found a larger than ordinary joint, in part converted into cleavable calcite, which flashed back reflected light, while the greater part showed the structure of the fossil in no degree effaced.

In the estimation of the temperature to which these erupted fragments had been heated, I operated upon the ordinary bitumenous shales of the district, on the imbedded shaley coke which is found in the tuff, and on the bombs of Lydian stone imbedded therein.

First, as regards the shales, that from the Kenly burn, the nearest point where it crops out, yielded—

S.G.	Water	Gas	Carbon	Ash.
1·79	4·54	25·29	9.27	60·09

That from Kinkell imbedded in the tufa—

2·57	2·64	6·	·44	90·92

The gas from the latter is non-combustible, or almost so. The shale from the tuff is grey-black,—very dark when the small amount of carbon is considered.

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From the Kinkell shale, therefore, the greatest amount of the gas and water has been distilled off, and the greatest amount of the carbon burnt away.

It was next ascertained that the shales of the district parted with their gas below a red heat, for antimony did not melt when inclosed along with them in the retort in which the distillation was conducted.

In working downward as regards temperature, in order to ascertain the lowest point at which the change could be effected, the following process was adopted.

A flat block of iron, of some pounds in weight, had a dome-shaped cavity turned out of one of its surfaces. On the surface of a large quantity of lead which had been melted and cooled in an iron pot, a number of fragments of the bitumenous shales were placed, and covered with the iron block, so as to be inclosed in and under the dome. The lead was melted in a dark room in a Bunsen furnace, which fitted closely round the sides of the pot, so that only the faintest glimmer of light escaped from between the surfaces of contact.

Upon the melting of the lead, the floating iron sank slightly into it, effectually inclosing the shale fragments. Very shortly after the lead had liquified, the iron was heard bumping against the sides of the pot; the sound of bursting bubbles was likewise audible; and wreaths of a flickering lambent vapour, which reflected apparently more light than that which escaped from the crevice in the furnace, were seen to ascend for a height of a foot or more, from around the sides of the floating iron. The form of the iron was clearly delineated in black shadow in the midst of these luminous fumes, while the surface of the lead emitted no light whatever. Whether these gaseous exhalations be phosphorescent or not, the experiment was not arranged to determine, they so appeared. This result sufficed to show that the organic matter could be and was driven out of the shale at a heat below redness.

Finally a quantity of the shale was next enclosed in a capacious iron retort, along with a large quantity of mercury, the retort placed in a furnace, and the orifice of its tube conducted beneath jars filled with water, and standing in the pneumatic trough.

There distilled over—*first*, water; *second*, carbonic acid, mixed with white vapours of a hydrocarbon; *third*, a combustible faintly illuminating gas; *fourth*, mercury along with vapours of paraffin, a highly illuminating gas, and a quantity of one of the paraffin oils; *fifth*, mercury abundantly, much heavy oil, and little feebly illuminating gas; finally after everything but mercury had ceased to distill, the retort was opened, when there was found much mercury remaining, with the fragments of shale, these

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upon examination were found to be unaltered in shape and bulk, they had darkened in colour, and were somewhat greasy in appearance.

On being analysed they yielded almost no volatile ingredients, and about 5 per cent. carbon, which is less than when decomposed by a red heat.

These shales, therefore, are decomposed partially at a temperature somewhat below that at which mercury boils; and totally, as regards illuminants, at that temperature.

Upon the examination of the Lydian stone bombs, it was found that they contained 6·9 per cent. of water, of which 1·01 was hygroscopic; now this quantity of water is about the normal for that mineral;—the heat therefore had not reached the point at which Lydian stone is dehydrated.

In operating to discover the temperature at which Lydian stone is dehydrated, it was found to lose, when continuously heated just below visible redness 1·963 p.c.; at a feeble red heat a total of 4·272 p.c.; at a full red a total of 4,503; and when heated to whiteness in the furnace 5·886 p.c. At the full red heat the powdered mineral slightly agglutinated, while at the white heat it fused to a blebby scoriaceous slag of a fawn colour—very similar in appearance to some vesicular lavas.

The data presented to us by the first experiments were that the shales had lost all their combustible ingredients, while the Lydian stone had not been deprived of any of its water. We have ascertained that the shales are totally decomposed at the temperature of boiling mercury, while the Lydian stone is partially decomposed at a heat below redness. We are therefore in a position to say that the temperature at which the ashes were finally ejected from the volcanic vents which ruptured the lower coal strata, probably lay between 660° and 900° Fah.

Let us now see what data we have to work upon, in attempting to estimate the temperatures at which ashes, cinders, mud and fragments of penetrated rocks, were ejected in Old Red Sandstone days.

As regards the augitic masses described, we have two circumstances to found upon; the first, that the included felspar—clearly one or other of the soda felspars—probably labradorite, had been so perfectly liquified that it had assumed spherical forms, a fact which also necessitates a *viscous* condition at least in those portions of the augite which included the felspathic spheres. The second, that we have, in the old cleavages and unaltered portions of the augitic masses, evidence either that the heat had not been high enough to vitrify them throughout, or that the period of time during which they had been subjected to that heat had not been sufficiently extended to enable them to be uniformly altered.

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In other words, the heat had been such as thoroughly to liquify the felspar, but not such as thoroughly to liquify *masses* of the augite.

What heat then had sufficed?

The process employed in the determination of the water in labradorites had shown that mineral and the plagioclastic felspars generally to be liquified at the temperature of a full, but hardly a bright yellow heat.

The point of liquifaction of the augites varies largely, from readily fusible varieties to the almost infusible diallage.

Direct experiments on the mineral in question were therefore necessary.

Preliminary trials with the blowpipe showed that ordinary sized chips of the mineral were only rounded on the edges, or fused with difficulty, in the best flame that could be obtained; but when subjected to Fletcher's blowpipe, in which the air and gas are both passed through red hot tubes before combustion, a perfect glass, of a colour somewhat paler than the mineral, was readily obtained.

A quantity in chips and powder was heated at gradually increasing temperatures in a platinum crucible; it was found that the highest heat of a fine Bunsen burner had no effect in causing agglutination, even when the crucible was enclosed in a jacket. The crucible and its contents were now subjected to gradually increased temperatures in Griffin's blast furnace; at a bright yellow heat there was no change, and only when the crucible was at the point of bright ignition, approaching to a white heat, did the powder coalesce and liquify.

According to Pouillet, this accords with a temperature of 2200° or 2250° Fah.

This tends to the conclusion that the depth at which the volcanic force operated at the epoch of the Upper Old Red Sandstone was much greater than at the time when the lower coal was disrupted.

As I had myself no means of sifting from the many reports in newspapers the true from the false as regards the finding of gold in the streams of Caithness, I applied to Dr. Joass, of Golspie, and found that his experience was confined to an unsuccessful search in the Duke of Portland's land, and in the neighbourhood of the Scarabins, while he indicates reasons for receiving with caution and doubt all reported finds; this he does for reasons which will be considered when the Sutherland gold is spoken of.

I then wrote to Dr. Lauder Lindsay, who has taken an enthusiastic interest in the matter for long. From him I have received the following list of finds *reputed*.

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"*Localities in Caithness of Gold finds, real or reputed, according to the newspapers of* 1869-70, *especially the* "*Northern Ensign*" (*Wick*), *in March and April*, 1869.

I. In the bed, over the banks of the Beriedele water, throughout its course, down to the sea beach.

II. In the Ord Burn, "in fair paying quantities."

III. In the Ausdale Burn ditto.

IV. On the Braemore estate (Sir Robert Anstruther's), through which the Beriedele flows.

V. On the Langwell estate, on the flanks of the Scarabin Hills, by Gilchrist, the originator of the Kildonan diggings of 1869.

VI. In the Langwell water.

VII. In the Dunbeath water, and

VIII. In the Burn of Haster.

IX. In the Lathernwheel Burn.

X. Various localities, the parish of Lathern: "existence proven."

XI. In the Thurso River, at various points, such as Weydale, Acharvadale, Halkirk, The Glut.

XII. In streams rising on Braemore.

XIII. In Strathmore, on Sir J. G. T. Sinclair's property

Special references to the *Caithness* gold localities are to be found in the "Northern Ensign" of February 4th, March 4th and 25th, and April 1st, 15th, and 22nd, all 1869.

In November, 1870, Sir J. G. T. Sinclair wrote to the "Northern Ensign," about gold that had been found on his property at Strathmore. Several other newspaper correspondents describe the *Caithness* gold—comparing it with that of Kildonan, but they do not give their names, so that the only "authentics" that can be cited in connection with *Caithness* gold are Gilchrist and Sinclair."

Dr. Lindsay thus reduces the "authentics" to two, and, as it is very improbable that Sir J. G. T. Sinclair personally found or even sought for gold, it is probable that the "find" was of the same character as the other "newspaper" ones. So that the flanks of the Scarabins would seem to stand as the only indubitable Caithness locality.

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The finest varieties of Caithness flags from the Castlehill quarries were analysed by Dr. Hoffmann* with the following results,—a so-called "bituminous shale" was also analysed—

	Top Flag	Middle	Bottom	B. Shale
Insoluble Silicates	68·4	69·45	61·39	69·96
Ferric Oxide and Alumina ..	10·21	11·5	4·87	8·15
Carbonate of Lime..	10·93	10 66	21·91	7·72
Organic Matter	3·88	5·79	3·4	10·73
Loss at 100° C.	·42	·4	·2	·53
Salts of Magnesia & Alkalies..	6·16	2·2	8·23	2·91

ADDENDUM.

Fearing that the absolute non-success in the discovery of the minerals which had attended the few traverses which I made in Caithness (and which had deterred me from further search in the county) might have militated against the fairness of my report thereon, I have, since the above was written, drawn upon the knowledge of my friend, Dr. Joass of Golspie, who has interested Dr. Robert Gunn of Culgower, in the matter.

Dr. Robert Gunn applied to his cousin Mr. John Gunn, of Dale, Halkirk, who enthusiastically "made enquiries in every parish in the county;" the notes which follow are extracts from his letters, which convey the results of the whole enquiry.

(1) Gold was found at Dirlot, but in small quantities. A whole day's work of four men produced only a bit about the size of a common pin-head. This was the only specimen of Caithness gold I ever saw. I remember hearing that gold was also found at Achardle, Harpsdale, on the Thurso. A friend in the Murkle Estates' office tells me that he saw some which was found somewhere near the Thurso river, but it was not much.

I am further informed that a gamekeeper at Strathmore, in this parish, found a large quantity of the precious metal at the time when the Sutherland gold fever was at its height, but he would tell no one where the locality where he made his find was situated. He is now dead, and I fear the secret has gone with him.

Iron was got in considerable quantities near Achavarasdale Lodge on on the property of Sir R. C. Sinclair. About 150 tons were shipped; it was wholly hematite and of first quality, and was found partly in vein and partly in *pots*. The vein was not followed to any great depth, and although the working was stopped some time ago, yet it was not because the ore was exhansted, but because the carriage was too much to allow of profit. There was excitement some years ago about iron being discovered

* "Quart. Jour. Geol. Soc.", vol. xv, p. 402.

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at Skinnet near Halkirk; and it was said that it was to be worked, but nothing came of it. Indeed, on making inquiries as to it, I can find no one who has *seen* iron-ore from that place, although several persons *say* it has been found there.

Iron-ore in small quantities was also found at Dirlot; as to its form it occurs in lumps of various sizes, but is of no value.

The Rev. Alex. Gunn, F. C. Manse, Walten, writes me:—

"With regard to the minerals of Caithness, I can give you very little assistance. As to metals, the field is a very barren one. I never heard of any gold being found in Caithness. Lead must also be rare, as I think it is generally associated with lime-stone, of which we have few deposits in Caithness. There is a small burn, about a mile or two from here, where I have heard small cubes of galena or lead-ore have been found, but I never had the curiosity to examine the place. The only iron I know of is found in various places, in the shape of irregular lumps, on or very near the surface of the ground, and is, I suppose, a sort of impure oxide in combination with clay. It is sometimes ground and used as paint by joiners, and makes a very good brown paint. Springs are often impregnated with it, and drains choked. There are some spots in this neighbourhood where it is very abundant."

Mr. Gunn also tells me where I can get a copy of Capt. Henderson's History of Caithness—a book I never before heard of. I will try to get the loan of it, as Mr. G. says it contains a good account of the mineral works in the county in past times. If you have not seen the book I will send you such extracts as may appear useful.

I got a specimen of the Dirlot iron-ore (?) which proves to be nothing more than the impregnated clay spoken of by Mr. Gunn. I can get plenty of the same stuff almost anywhere in this district.

Silver and lead have been found at Skinnet, near Halkirk, both of average quality, and the latter has been also discovered at Borrowstone, near Reay. I am informed that a lot of lead (very near the surface) was lately discovered at Brawl, between Skinnet and Halkirk. I have succeeded in getting a specimen, weighing 3½lbs of this, which I forward Please advise the arrival of it and of the hematite.

"The late Sir John Sinclair, Bart., of Ulbster had, in his day, parties prospecting for coal on and around Spittal Hill in this parish. Although they were unsuccessful yet they found *something* like what they were in search of. As this took place some sixty years ago, I am unable to say what the *something* was."

. Henderson, of Westerdale, has a limestone quarry on her property she works; it is, I am informed, of very good quality. Limestone

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was worked here at Dale, by my grandfather, the late Capt. Gunn, but the strata dipping it became at last too expensive to work."

Of the specimens kindly procured by Mr. Gunn and forwarded to me by Dr. Joass, I have to note that those from Achavarasdale are *limonite*, and not hematite as supposed by Mr. Gunn. One specimen is in well developed botryoidal forms, and has an appearance in colour and streak so intermediate between limonite and hematite that I regret much that its late arrival has prevented me from analysing it. In another massive granular specimen there are cavities lined with downy crystals, possibly of Göthite. A third specimen carries small doubly-terminated crystals of quartz, pleasingly stained and "capped" internally with yellow ochre. Taking the average of the specimens I have seen from the locality they are very far from "first quality."

The *galena* from Brawl is excellent, but its large foliation, and the dull blackness of its powder, indicate an unusually small percentage of silver. It had on it a small quantity of *cerussite*.

The Skinnet and Dirlot iron-ore is evidently *bog-iron-ore*.

Dr. Joass writes me—"I have come upon *a deed* among the Dunrobin papers which speaks of "all mines and minerals whatsoever whether Lead, Tin, Copper or even Coals," but which does not state that any traces of either were apparent. Anyhow nothing came of it."

"*Nothing came of it.*"—words used by Mr. Gunn also; they have to be written of all mineral enterprise in Caithness, whether scientific or sordid.

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III.—*List of Newfoundland Minerals.*

By J. P. Howley, of the Newfoundland Geological Survey.

THE following list includes only such minerals as have come under my own observation, or that of such authorities as can be relied upon. Amongst the latter I may mention, Mr. John Milne, Professor of Mineralogy, Yedo, Japan; the late Mr. Hennessey, M.E., and Mr. Barclay, assayist, Belt's Cove Mine.

I have adopted Dana's nomenclature as that most familiar on this side of the Atlantic, and have arranged the names alphabetically, for convenience.

Alum shale.
Antimonite.
Apatite.
Argentiferous Galena.
,, Pyrites.
,, Quartz.
AUGITE.
Auriferous ,,
BARYTA (sulphate of)
Bismuth, traces.*
Bitumen (crystalline.)
Blende.
BRONZITE.
Cadmium, traces*
CALCITE, Iceland spar.
,, DOG-TOOTH spar.
,, NAIL-HEAD ,,
Chalybite.
CHLORITE.
Chromite.
Chrysolite.
Chloanthite.
COAL (bituminous)
Cobalt, traces*
COPPER, native
COPPER GLANCE.
COPPER PYRITES.
COPPER, Red Oxide.
Cyanite.
DIALLAGE.
DOLOMITE.
Enstatite.
EPIDOTE.
ERUBESCITE.
FELDSPAR, Orthoclase.
Fluor
GALENA.
GARNET.
Gold, native*
GRAPHITE.
GYPSUM, SNOWY.
,, SELENITE.
HORNBLENDE.
,, ASBESTUS.
,, ACTINOLITE.
HEMATITE.
Horn Silver*
Hypersthene?
ILMENITE.
IRON PYRITES.

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IRON JASPERY ORE.
,, BOG ORE.
KAOLIN (clay).
LABRADORITE.
MAGNETITE.
MALACHITE.
MANGANESE (carb. of)
MICA.
Millerite.
MISPICKEL.
Molybdenite.*
NICKEL COPPER.
OCHRE, RED & YELLOW.
Opal.*
Petroleum.
PSILOMELANE?
Pyrosclerite.
PYRRHOTINE.
QUARTZ.
QUARTZ, ROCK CRYSTAL.
QUARTZ, AMEYTHSTINE.
,, CHALCEDONY.
,, AGATE.
,, JASPER, FLINT, &c.
Rhodonite?
Rutile.
SALT (common)
SERPENTINE.
,, PICROLITE.
Silver, native*
,, Ruby.*
STAUROLITE.
TALC.
,, STEATITE.
TETRAHEDRITE.
Tombazite* (Gersdorffite)
TOURMALINE.
,, RUBELLITE.
Vivianite?*
WAD.

In the above list the large type indicates common species, those marked with an asterisk are rare, and the note of interrogation denotes doubtful minerals.

The apparent absence of many important groups, and the paucity of species generally, is not so much indicative of their non-existence, as of the fact that so few persons here are interested in their collection. Those who are at present engaged in the development of our mines, pay little attention to any minerals not of a commercial value; while my own opportunities of collecting have been hitherto chiefly prevented by an excess of topographical and geological work. I have no doubt that in course of time, however, I shall be enabled to add many others to the list, which is merely preliminary to a more extended one.

Newfoundland is just beginning to take its place amongst the mining regions of the globe; as yet her copper ores only have attracted attention. It is but reasonable to suppose that the time is not far distant, when many of her other economic materials will be profitably wrought. This supposition is founded on the fact that the latest rock deposit is of no more recent date than lower carboniferous, while the 42,000 square miles, which comprise the surface area of the island, are spread over by most of the older or pre-carboniferous formations. Many great belts of intrusive and metamorphic rocks cross the island

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diagonally, or occupy immense areas, both in the interior and along the coast-line; in which frequent indications of various mineral substances are known to occur.

The absence of railways, or any means of interval transport, necessarily renders all products not immediately on the sea coast unavailable at present; and for the same reason it is now a difficult matter to get about the interior, or make any extensive collection of minerals, owing to the difficulty of conveying them hence.

In connection with this subject, a short notice of the principal mining localities, and the mode of occurrence of the ores, &c., may not be out of place.

The mines of Tilt Cove, Belt's Cove, Naked Man, Little Bay, Hall's Bay, Rabbit's Arm, and Seal Bay are all situated in the Great Bay of Notre Dame; the principal ores worked being those of copper. Yellow sulphide, of a low percentage, ranging from 6 or 7 per cent. to 30 per cent., forms the chief product. The low percentage of the ore in the abovenamed localities is counterbalanced by its abundance. Tilt Cove shipped between the years 1867 and 1873, 33,687 tons; and Belt's Cove, in less than five years from its inception, the enormous quantity of 95,000 tons. Little Bay mine was only opened in August, 1878, and had shipped to the end of that same year 10,000 tons. The other localities mentioned above have only recently been opened up, and as yet there have been no returns from them. Copper ore occurs in many other parts of this Bay, often of a very promising character. The ore is found chiefly embedded in chloritic slate, or as at Tilt Cove, in a compact chloritic rock; but at Rabbit's Arm it occurs in parallel bands of quartz. Much of the ore in the slate bands presents the appearance of stratification, or at least corresponds with the bedding of the slate; even partaking of the various corrugations of the latter. Huge masses frequently occur, especially where the bed rocks are most affected by sharp folds, or otherwise disturbed.

Native copper is found sparingly in the Tilt Cove mine, and as thin films, frequently of a beautiful arborescent form, is also met with in a few other localities in this Bay. It occurs on the west coast of the island, in small strings and nodules, in Port-a-Port Bay and Bay of Islands; where it is found embedded in an amygdaloidal trap rock. Copper Pyrites is met with in many other parts of the island and nearly every one of its great bays, but nowhere in such quantity as in Notre Dame Bay. Variegated copper ore, copper glance, erubescite, tetrahedrite, &c., occur at several parts of Conception Bay, usually in quartz veins; and again on the east coast, and in Placentia Bay.

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Beautiful specimens of what the miners term Peacock ore have come from the latter place.

Some of these ores are very rich, yielding between 75 and 80 per cent. copper; but hitherto, though several attempts have been made to work them, the result has been in each case an unprofitable one. Nickel has been found by analysis, together with Cobalt, in many of our serpentine rocks, but the former ore has only been met with in workable quantities at Tilt Cove. One hundred and sixty-five tons were shipped from there previous to the recent fall in price.

Copper Nickel and Chloanthite are the principal ores, small quantities of Millerite and Tombazite (Gersdorffite) being associated with them in a gangue of a dolomitic character.

Iron ores are abundant in the island, and are found in association with all the copper ores, especially pyrites, which forms fully half the products of these mines. Magnetic iron, in great masses, accompanies the Tilt Cove copper ore, but occurs more sparingly at the other mines. It is met with also in several other localities, notably, amongst the Laurentian granites and gneiss. Chromic iron in association with serpentine rocks, frequently occurs. All the other ores of iron mentioned are quite common, being generally distributed over most parts of the island.

Lead (galena) is also a pretty generally diffused ore, but has so far only been worked in one or two localities. Its gangue is either calcspar or quartz, except in one noted instance, at a place named Laun on the southern coast, where it occurs in a matrix of greenish fluor spar. The ore has been worked for many years at the La Manche Mine in Placentia Bay, from a vein of calcspar averaging 6 feet in width, which was well charged with galena, and contained also a little copper pyrites. Beautiful amethystine quartz crystals were found lining vughs in this vein, which also yielded the opal mentioned, the only one I have ever come across.

Lead has been worked in Port-a-Port Bay in a matrix of crushed carboniferous limestone, which afforded a considerable quantity of ore, but the work had to be suspended, owing to the anomalous position in which we are placed in reference to that part of the island. Most of the galenas contain a small percentage of silver. It has also been found by analysis in an ore of iron from Bonairsta Bay, and in quartz from Bay of Islands. Native silver, horn silver, and ruby silver, in small quantity were taken from the Laun Lead Mine referred to above.

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Gold has as yet been found but sparingly in quartz veins; some good specimens were recently brought from the neighbourhood of Brigus in Conception Bay. Its existence in quartz from several localities, and also in some of the iron and copper ores, has been proved by analysis; and there is every reason to believe that ere long it will be met with in quantities sufficient to render it of economic importance.

Zinc Blende is usually found in association with the lead and copper ores, but not in any great quantity. A reddish variety from the Laun Mine yielded traces of cadmium.

Rutile occurs in vitreous quartz in White Bay.

Molybdenite also in quartz, has only been found at Deer Lake, on the Humber River.

Antimonite, associated with galena and zinc-blende, is found at Morton's Harbor, in Notre Dame Bay. Manganese in the form of wad is very common. A massive black variety which I have called Psilomelane? and also Rhodonite? forms a considerable deposit near Topsail, in Conception Bay.

Baryta, or heavy-spar is a pretty abundant mineral; a wide vein, having a pinkish tinge, is seen near St. Brede's in Placentia Bay.

Coal is confined to the carboniferons areas on the western side of the island; one in St. George's Bay, and the other near the head of Grand Pond on the Humber River. In the former area several small seams are known to exist, only two of which appear to be of sufficient thickness to be economically important. During last summer a bore hole was tried in the latter area, which resulted in the finding of five small seams, the largest of which was but 1·4 inches. Gypsum in immense masses, frequently of a superior quality for stucco work, accompanies the lower carboniferous limestones in these regions. Veins of beautiful selenite are met with at times traversing these masses.

Petroleum in small quantity is seen oozing through the sand on Shoal Point, Port-a-Port Bay.

To enter into particulars of the various localities in which the more common earthy minerals occur would render this paper needlessly long. It will be sufficient to state generally, that the siliceous varieties are common throughout the island, while those partaking more or less of a magnesian character, usually accompany the metamorphic serpentinous groups of rock.

The aluminous varieties, especially the felspars, labradorites, garnets, tourmalines, cyanites, staurotides, micas, &c., are found in

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abundance amongst the rocks of Laurentian age, but are not all confined to this formation.

The crystalline Bitumen, which was obtained from a brecciated trappean mass, intersecting Lower Silurian limestones, &c., in Port-a-Port Bay, seems to have resulted from the heating action of the igneous mass coming in contact with a set of bituminous limestones and shales. It is from the latter rocks also that the Petroleum is derived.

Brine springs, containing much saline matter, accompany the gypsiferous deposits of the carboniferous formation, and the rocks in their immediate vicinity are frequently incrusted with a fine coating of salt.

It may be worthy of note that the ruby silver, found at Laun, has not, I understand, been met with any where on the continent north of Mexico.

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IV.—*On a peculiar pasty form of Silica, from a cavity in Gold-bearing Quartz.*

By A. French.

THE alluvium over an area of about 50 square miles around Lead-hills in Lanarkshire, is auriferous. In many places the precious metal may be rendered visible after fifteen or twenty minutes washing with the primitive wooden trough employed by the local gold-seekers. Frequently nuggets have been found weighing from one to four or five pennyweights, and these are often either contained in pieces of loose quartz, or have quartz fragments attached to them; there are therefore good reasons to believe that the gold found in the red stratum of clay lying immediately above the rock has been derived from the numerous quartz veins which traverse the district.

The author was one day searching, along with some friends, for gold quartz *in situ*, and while examining a vein which crosses a gulch in the hills, called the "Gold Scars," found cavities in the quartz filled with a peculiar pasty substance, which appeared at first sight like minute scales of silver, which had been precipitated from a solution. Our first impression was that it was silver, but its behaviour in water soon cleared away the delusion; it rendered the water exceedingly turbid and white, and the suspended matter was a long time in settling. It consists of very minute scales of silica, somewhat lenticular in shape, their sizes vary from $\frac{1}{2000}$ to $\frac{1}{6000}$ part of an inch.

It is not attacked by hydrochloric or sulphuric acids, but is easily dissolved by hydrofluoric acid, and by a moderately dilute solution of sodium hydrate.

It is a rather remarkable feature of the Lead Hills district that the lead and gold bearing ground is bounded on four sides by particular kinds of quartz. On the southern boundary Lydian stone is found in great abundance. On the north at Abingten, red jasper prevails; towards Crawfordjohn on the west agates and cornelians are found, —these are sometimes of great beauty; and on the east near where this specimen of silica was found, calcedony is often found.

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The whole field is contained within the Lower Silurian, the palæontology of the district is exceedingly meagre, but mineralogically it is very productive.

In the discussion which ensued on the reading of this paper some doubt was expressed as to the substance being really silica. Some members thought it was rather a sub-carbonate or other sub-salt of lead. I therefore requested Mr. Collins to test the small portion which I had previously placed in his hands for exhibition at the meeting.

He reports as follows:

"The quantity of material placed at my disposal was too small to allow of a proper chemical analysis by humid methods. I have, however, obtained very definite results by pyrologic tests. Thus, I found it unaltered in the closed tube, however strongly heated; it effervesced strongly when fused into a bead with carbonate of soda, and it remained insoluble in a bead of microcosmic salt. These results are quite sufficient to prove the presence of silica, and the absence of such bases as colour a bead of microcosmic salt. The absence of alumina was shewn by the nitrate of cobalt test. On the whole I see no reason to doubt that it is really silica as you say."

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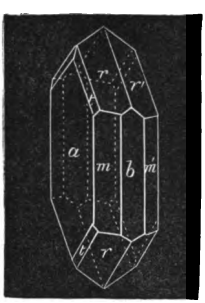
V.—*On a new face on crystals of Stilbite, from two localities.*

By Professor Heddle.

MANY years ago I observed upon crystals of the red stilbite, which was at one time obtained near Loch Humphrey, and at the Long Cray, in Dumbartonshire, a face which is between *r* and *a* of Brooke and Miller.

More lately I have observed a face which also lay in the same position upon the crystals of a specimen ticketted as from Farrugaric-Wuardi, near Mount Nombi, west side of Wellington Plains, Australia.



In none of the specimens which I have, was this face very smooth; and having failed to obtain better, I now note it, though the measurement can be little better than an approximation.

In the Australian specimen the angle $a\ t = 152° 32'$ to 153°.

On the Scotch specimen it is rougher from its being striated parallel to its intersection with *a*; it seemed about 149°45′ to 150°. I have little doubt, however, that it is the same face as that on the Australian crystals.

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Reviews and Notices.

Chapters on the Mineralogy of Scotland, by Prof. M. Forster-Heddle, F.R.S.E.

Trans. Royal Soc., Edinburgh, Vol. XXIX, Chap. VI.—Chloritic Minerals. Read 3rd March, 1879.

ANOTHER of our esteemed President's interesting "chapters," not less important than those which have gone before.

The author commences his paper with some general remarks upon Mineralogical classification, and upon the use of the terms "chlorite" and "chloritic mineral," as follows:—

> There is no department of natural science which is so defective in its general scheme of arrangement as mineralogy; and its sectional grouping is, if possible, still more defective.
>
> Such correlations as are expressed by the terms, "The Micas," —"The Felspars,"—"The Garnets," &c., are only admissible if the substances united in such groups are included under one general formula, and function in a more or less similar manner as rock-formers.
>
> Under such methods of arrangement as are in vogue, many substances are left to stand isolated as intermediates,—substances which frequently form important integers in a regular sequence. And when such groups are constituted upon the possession of merely some one general feature, it almost invariably results that there are linked together substances which have nothing else in common.
>
> Mineralogy presents numberless examples of the misleading effect of being guided by mere externals; and the more the *geognostic relations* of minerals are sought out, the more clearly do we see the false conclusions with which we are drawn when we *are* guided by externals alone.
>
> To no group does this apply more emphatically than to that of "*The Chlorites.*" Of the twelve minerals which in our systems find a place therein, some are the products of mere solution—some of direct chemical change,—some of metamorphic transmutation. Of these, some are found in sedimentary rocks, some in volcanics, in limestone, in serpentine, in schists, in granite, and in traps.
>
> The extreme injudiciousness of founding a natural history group upon so trivial a character as *colour* alone, is shown by the laxity which has gradually crept in, by the expanding as it were of the name into "the Chloritic group," or "Chloritic minerals."

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From the difficulty of discriminating between several substances which fall under such a term, there can be no doubt that it has not unfrequently been adopted as a convenient cover for ignorance.

"I always say *chloritic minerals* when any of my students ask me what they are,—it covers a vast amount of ignorance." This was the remark made to me by a teacher of geology, when we were discussing the green substances which plug the steam holes of anygdaloids. The deductions to be drawn from the present investigation, will show that the term employed instead of covering, *exposed* that which it was intended to conceal.

From the very frequent occurrence of diffcultly-recognisable green minerals in volcanic rocks, it is to them that this term of chloritic is now *specially* applied; it is so applied in the belief that the mineral is a chlorite of some kind, and this is conceived to be quite a sufficient amount of knowledge.

In proof that there has been no overstatement in the foregoing remarks, Dr. Heddle refers to Mr. J. Clifton Ward's "Notes on the occurrence of Chlorite . . . . in the English Lake District,"* and to the writings of Von Cotta, who, in defining diabase says "and some chlorite" . . . . "The green colour of the rock is chiefly owing to its chlorite.

"The most marked feature of its difference from dolerite is its chlorite, and its consequent green colour. If this chlorite be a product of transmutation, then all the original difference between diabase and dolerite probably consists in the level or depth of solidification."

Dr. Heddle continues:—

It is significant that Cotta does not enumerate chlorite among the minerals accessory to diabase, its clefts and veins; while he says "the vesicular cavities are filled with . . . chlorite, glauconite . . . . and the like." It is well known that the veins of a rock contain the materials of its general structure in giant development of crystals, while its amygdules contain the products of the transmutation thereof, through aqueous change and transfer.

Lately, however, clearer light is beginning to be thrown on the matter, for we have Dana supporting Rosenbusch, when he says that chlorite is not an essential characteristic of diabase; and those who look in Scotland for chlorite in rocks, in all other respects entitled to the name of diabase, will certainly find none.

If we are to accept and found upon the above admissions, namely, that the amygdules of these so-called chloritiferous vol-

* Since this review was placed in the printer's hands, the untimely death of this most active and able geologist has been announced—to the great and we fear permanent detriment of the Scientific Societies of Cumberland, for whom he acted as a bond of union.

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canics contain the material which, diffused in a minute-granular or flakey condition throughout their mass, imparts the occasional green tint, then analysis has determined that material to be in no way connected with chlorite, except in colour.

The results of the following investigation go to show that the minerals usually thrown together under the term which I somewhat unwillingly adopted as the heading of this chapter, are to be grouped under two absolutely distinct heads. For the first, the old term of *the chlorites* may be retained; to the second, the term *the saponites* may be applied, from the unctuous feeling, which is a marked characteristic of them all.

So far as the evidence of over fifty analyses, and much contingent observation, entitles me to speak, the members of the first of the groups are found only in sedimentary and metamorphic rocks, never occurring in volcanics; the second are confined invariably to the latter, never being seen in the former class of rocks. The members of the first are not decomposed by chlorhydric acid, and there is no peculiarity in the manner in which their constituent water functions.

The members of the second are (with one exception) readily decomposed by chlorhydric acid, and the mode in which a portion of their constituent water is held in combination is anomalous.

The first are to be regarded as constituents of the rock mass which contains them, paragenetic in time with the minerals associated with them. The second are products of the degradation of the primal constituents of the rock, and are compounds of a more stable nature than the originals which yielded them through a destructive change.

So far as I have yet ascertained, the following members of each of these groups occur in this country.

	Chlorites.	
Glauconite	Penninite	Chlorite
Talc-chlorite	Ripidolite	Chloritoid
	Saponites.	
Delessite	Hullite	Celadonite
Chlorophæite	Saponite	

As regards *the Chlorites*, after some general remarks upon the physical characters, which the author says "lend scarcely any aid, if they do not even somewhat confuse" as regards their determination, and referring to the dearth of information as to the geognostic relations of minerals, Dr. Heddle proceeds to describe in detail the localities, modes of occurrence of each of the Scottish species, and gives full chemical analyses—these latter being epitomized in table 1.

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PENNINITE.

	S. G.	$\dddot{Si}$.	$\dddot{Al}_2$	$\dddot{Fe}_2$	$\dddot{Cr}_2$	$\dot{Fe}$.	$\dot{Mn}$.	$\dot{Ca}$.	$\dot{Mg}$.	$\dot{K}_2$	$\dot{Na}_2$	$\dot{H}_2$	Totals.	Matrix.
Scalpay, Harris	3·099	30·41	11·58	2·34	...	10·71	1·19	tr.	30·63	·01	1·31	11·74	99·92	Serpentine
Corrycharmaig, G. Lochy...	2·895	34·31	13·64	·36	tr.	10·31	·23	8·97	18·04	1·36	·13	12·41	99·75	Mica slate.
Kammererite—														
Unst, massive	3·099	29·89	12·93	...	5·97	1·96	...	3·54	29·93	1·16	·97	13·27	99·62	Serpentine
Do., crystallised...	...	32·31	7·5	...	7·89	2·08	...	3·83	32·15	...	...	14·25	99·9	Do.
Pseudophite or (?) *Pyrosoclerite*—														
Beauty Hill, Aberdeen ...	2·59	34·73	12·44	...	...	2·68	1·17	1·6	34·1	...	...	13·1	99·82	Gabbro.

RIPIDOLITE.

Blair Athol	...	30·3	19·4	...	...	8·23	·37	...	29·1	...	...	13·07	100·47	Limestone
Hillswick, Shetland	...	32·55	13·95	·97	...	5·28	·16	·79	32·78	·48	·06	13·17	100·19	Chlorite slate
Cape Wrath...	2·823	31·03	14·85	5·73	...	17·42	1·	·36	17·42	...	...	12·48	100·29	Hornblendic gneiss
Aphrosiderite—														
Bishop's Hill, Argyll... ...	2·959	35·41	18·08	·48	...	26·47	·61	1·01	8·77	·98	·52	8·03	100·36	Chlorite slate

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TABLE 1—*Continued.*

	S. G.	$\dot{Si}$.	$\dot{Al}_2$	$\dot{Fe}_2$	$\dot{Cr}_2$	$\dot{Fe}$.	$\dot{Mn}$.	$\dot{Ca}$.	$\dot{Mg}$.	$\dot{K}_2$	$\dot{Na}_2$	$\dot{H}_2$	Totals	Matrix.
CHLORITE.														
Fethaland, Shetland... ...	...	24·3	20·86	3·57	...	16·72	·55	·5	22·2	...	...	11·55	...	Mica gneiss.
Ben Derag. Perthshire ...	3·002	24 72	21·57	·62	...	26·16	·47	·45	12·86	1·73	·05	10·89	99 51	Mica slate.
Craig-an-Lochan, do ...	2·697	24 29	21·18	·10	...	18·74	·8	1·66	21·03	1·29	·56	10·08	99·7	Do.
Lude, do ...	2 852	23 92	22·98	1·11	...	19·54	·28	2·45	17·26	...	...	11·78	99·39	Limestone.
Do., do ...	2·852	24 66	23 19	·64	...	20·58	·29	·4	17·79	...	...	12·12	99·66	Quartz in ditto.
Loch Laggan. Inverness ...	2·834	26 25	19·22	1·67	...	16·44	1·02	...	24·35	...	...	11·67	100 62	Limestone.
Portsoy, Banffshire	2·792	26·71	20·42	3 47	...	13 99	·73	...	23·9	...	...	11·17	100·39	Chlorite slate.
Girdleness, Kincardine ...	3·038	24·77	20·16	1·38	...	27·39	·61	·9	13·34	...	...	12·05	100·59	Granite vein.
											...			
CHLORITOID.														
Hillswick, green...	3·387	24·47	41·34	·38	...	18·52	·91	·3	6·8	...	...	6·98	99·71	Mica slate
Do., brown	3·356	25·36	41·74	3·89	...	13·93	·92	90	6·82	...	...	6 57	100·41	Do.
TALC-CHLORITE.														
Hillswick	...	39·81	11·43	...	...	7·97	·26	2·80	25·68	1·2	3·15	7·91	100·19	Chlorite slate
GLAUCONITE.														
·hgrove, Eligin	...	49·09	15·21	10·56	...	3·06	...	·55	2·65	6·05	1·21	11·64	100·02	Cornstone.

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He then does the same for *the Saponites*—the analyses being here given in table 2.

TABLE 2.

	S. G.	Loss at 212°	$\ddot{Si}$.	$\dddot{Al}_2$	$\dddot{Fe}_2$	$\dot{Fe}$.	$\dot{Mn}$.	$\dot{Ca}$.	$\dot{Mg}$.	$\dot{K}_2$	$\dot{Na}_2$	$\dot{H}_2$	Total.
DELESSITE.													
St. Cyrus, Kincardine	2·652	2·744	32·69	13·44	4·4	6·62	...	·86	28 77	...	...	13·25	100 02
Bowling Quarry, Dumbarton ...	2·573	5·7	32·	17 33	1·19	12 45	...	1·57	20·42	...	...	15·45	100 4
Dumbuck, do. ...	2·598	6·3	32·01	18·87	1·18	12 09	tr.	1·39	19·64	...	...	15·16	100·64
Long Craig do. ...	2·656	4·678	30·93	15·32	3·16	15·31	·38	1·38	18·65	...	...	14·69	99 82
Elie, Fifeshire...	2 672	3·389	30 69	12 83	1·63	18 32	1·	1·59	18 6	·57	1·11	13·77	100 11
Average	2·63	4·562	31 26	15·56	2·32	12·96	...	1·38	21·22	...	...	14·52	...
Formula	...	...	31·53	16 28	2·8	12·61	...	...	21·02	...	...	15·76	...
CHLOROPHÆITE.													
Scuir Mohr, Rum	...	19·227	36·	...	22 8	2 46	·5	2·52	9·5	tr.	tr.	26·46	100·25
Giant's Causeway, Ireland	2·278	14·156	35·99	10·49	11·89	1·63	·08	5·15	10·52	·34	·76	23·2	99·99
"Hullite" (hydrated)	...	...	35·06	9·21	18·42	3·25	tr.	3 99	6·65	...	...	23·2	99·78
HULLITE.													
Kinkell, Fifeshire	...	8·029	38·59	17·34	15·97	n. d.	1·56	3 94	8·65	·67	...	13·48	100·2
Carnmoney (Hardman)...	1·76	...	39·44	10·35	20·72	3·7	...	4·48	7·47	...	...	13·62	99 78
Average	...	...	39·	13·84	18 35	3·7	...	4·48	8·06	...	...	13·5	...
Formula...	...	...	38·77	12·44	19 38	3·55	...	4·04	8·72	...	...	13·1	...

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TABLE 2—*Continued.*

SAPONITE.

	S. G.	Loss at 212°	$\dot{\dot{S}}i$.	$\dot{\dot{A}}l_2$	$\dot{\dot{F}}e_2$	Fe.	Mn.	Ca.	Mg.	K_2	Na_2	H_2	Total.
From "Old Red" Volcanics—													
Gapol, Kincardineshire	2·179	15·746	42·13	7·25	6·57	·19	·13	·8	19·33	·58	2·09	21·07	100·14
Kinneff, do. (green) ...	split	14·092	42·1	5·95	4·96	·18	·09	2·15	20·98	·28	·46	22·93	100·08
Do. do. (purple) ...	2·28	14·52	42·5	5·88	4·91	·12	·12	2·13	20·74	·19	·47	22·75	99·79
Glen Farg, Perthshire	2·235	12 961	36 54	9 39	2·85	5·25	·15	2·5	21·62	...	...	21·68	99·97
Wormit Bay, Fifeshire	...	13·87	42 84	4·83	6 5	2 36	·2	2·16	21 81	tr.	...	20·7	101·39
Tayport, do.	2 282	13 96	40·11	6·49	5·61	2·37	tr.	2 01	21·67	·32	·21	21·6	100·38
Catkin Hills (scaly)	2·279	15 61	41·34	10·53	1·86	3·84	·09	1·22	21·07	·05	·37	19·48	99·48
Do. (fibrous) ("Bowlingite")	2·288	14·76	42·22	8·52	2 99	4 88	·07	·92	21·23	...	...	19·49	100·31
Bowling Dumbarton (do.)	2·308	12·315	38·08	6·26	4·36	4·98	·23	2·97	21·46	·95	·11	20·48	99·96
Do. do. (Mr. Dalziel)	...	12 965	36 74	5·35	5·94	6·96	·08	3 06	20·22	·49	·21	21·28	100·31
From Secondary Volcanics—													
Storr, Skye (olive)...	2·296	13·652	41·41	9·08	2·05	...	·11	1·86	22·8	...	...	23·43	100·72
Quiraing, Skye (white)	split	15·536	42·5	5·06	·85	...	·23	3·27	23·95	·17	·45	23·68	100·14
Do., do. (yellow)	split	15·132	40·33	8·72	1·97	...	·13	2·8	21 71	...	...	24·34	99·99
Average	2·272	14·22	40 63	7·18	3·96	2·38	..	2·14	21·43	...	...	21·76	...
Formula...	...	...	40·81	7·5	3·88	2·62	...	2·04	20·61	...	...	22·73	...

CELADONITE.

Scuir Mohr, Rum	2 574	5·99	57 72	·33	17·05	3·73	·08	·6	3 84	5·55	·42	10·78	100·2
Tayport, Fifeshire	2·59	5·018	52·69	5·79	9·75	5·37	·31	1 16	8·54	6·21	·39	10·48	100·68
Wormit Bay	2·598	3·879	52·54	5·82	9 71	5·4	·3	1·29	8·31	6·5	·64	10·41	100·93
Giant's Causeway, Ireland	2·63	1·364	56·41	2 14	14·07	5·09	·23	·6	5 91	8·83	...	6·79	100·29
Average	2·598	...	54 84	3·52	12·64	4·9	...	89	6·65	7·	...	9·62	...
Formula...	...	...	54·05	3·83	11·94	5·4	...	...	6·76	7·88	...	10 14	...

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These tabulations present clearly to the eye the distinctive features of these allied minerals, which are therein arranged in the order of their content of Silica.

The following formulæ are then given for the five *Saponites*—

Delessite $(\dot{F}e^{\frac{1}{2}}\ \dot{M}g^{\frac{1}{2}})^3\ \ddot{S}i^3+(\ddot{A}l_2\ _{\frac{1}{10}}\ \ddot{F}e_{2\ \frac{9}{10}})\ \ddot{S}i+3\dot{H}_2+2\dot{M}g\ \dot{H}_2$.

Hullite $(\dot{F}e\ \dot{C}a\ \dot{M}g)^4\ (\ddot{A}l_2^{\frac{1}{2}}\ \ddot{F}e_2^{\frac{1}{2}})^3\ \ddot{S}i^3+9\dot{H}_2$.

Saponite $(\dot{F}e\ \dot{C}a\ \dot{M}g)^6\ \ddot{S}i^6+(\ddot{A}l_2^3\ \ddot{F}e_2)\ \ddot{S}i+13\dot{H}_2$.

Celadonite $(\dot{F}e^{\frac{1}{2}}\ \dot{M}g^{\frac{1}{2}}\ \dot{K}_2^{\frac{1}{2}})^3\ \ddot{S}i^6+(\ddot{A}l_2^{\frac{1}{2}}\ \ddot{F}e_2^{\frac{1}{2}})\ \ddot{S}i^3+5\dot{H}_2$.

Chlorophæite Formula not evident.

Or, in atoms—

Delessite $\dot{R}^4,\ \ddot{R}_2,\ \ddot{S}i^3\ \dot{H}_2^5$.

Chlorophæite $\dot{R}^4,\ \ddot{R}_2^3,\ \ddot{S}i^7,\ \dot{H}_2^{10}$.

Hullite $\dot{R}^4,\ \ddot{R}_2^3,\ \ddot{S}i^3,\ \dot{H}_2$

Saponite $\dot{R}^6,\ \ddot{R}_2,\ \ddot{S}i^7,\ \dot{H}_2$.

Celadonite $\dot{R}^3,\ \ddot{R}_2,\ \ddot{S}i^6,\ \dot{H}_2^5$.

In the above investigation every substance, the nature of which was at all doubtful, of which I could obtain a sufficiency for analysis was examined.

In applying the results of the examination to the consideration of the geognostic relations of these minerals, those of the first or true chlorite type may be dismissed in few words.

With the exception of the occurrences of chlorite at the Girdleness and at Rubislaw in granite, the minerals of the first class are to be found *only in metamorphic rocks*.

Glauconite, occurring generally in rock which is believed to be of recent origin, may, by its occurrence, aid somewhat in assigning the age of certain doubtful strata.

The second group, which I have called the saponites, belong *solely to igneous rocks;* and, from the mode of their occurrence, there is no room for doubt that *they result from the alteration of certain of the constituents of these rocks*—augite and olivine in all probability.

As regards our power of distinguishing them from each other, this is by no means so difficult as their want of form and general similarity of appearance would at first sight lead one to suppose.

Delessite can be distinguished from chlorophæite by its dull lustre, its minutely granular structure, its opacity, and its colour —in the field; and rapidly in the laboratory by its much higher

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gravity, its much smaller loss at 212°, and much smaller total content of water.

From the specimen of Hullite found at Kinkell, I could not by physical properties undertake to distinguish it;—the darker varieties of Delessite at least much resembled that specimen.

From saponite, Delessite can be distinguished by its dark colour and granular structure and its opacity; and in the laboratory by its high gravity and its water.

From celadonite it could not be distinguished either by its structure or opacity, or by its gravity, or satisfactorily by its water content; but its colour, and its solubility in acids, at once suffice to separate the two.

Chlorophæite is readily recognised; when fresh it resembles a green jelly,—when weathered it equally resembles drops of asphalt.

The Kinkell Hullite resembles a dark Delessite, and therefore does not resemble chlorophæite.

Saponite, it its usual green form, is easily known; its extreme softness, greasy lustre, great translucency and soapy structure suffice to define it in the field; the extreme readiness with which it parts with and regains so large a quantity of water equally suffices in the laboratory, while its low gravity is of itself characteristic.

The white variety is by no means so readly identified; halloysite, conite, the magnesian carbonate of lime, agaric mineral, and a peculiar superhydrated vein-serpentine, all closely resemble it.

Celadonite may at once be known by its insolubility in acids; its loose-granular or mammillated structure, its perfect opacity, and brilliant colour, are likewise well-marked characters.

Such are the minerals occurring in Scotland, which are without question to be referred directly to one or other of the above species.

The author then gives a description of the new mineral *Bhreckite*, already described in the *Mineralogical Magazine* (p. 57, vol. 11), and of *Rubislite*, a mineral much like a *Hullite*, in which much of the iron is in a ferrous condition, and which was found in the red granite of Rubislaw.

The paper concludes with the two following "supplements."

Supplement to Saponite.

In a letter from Professor King, received since the foregoing analyses of saponite were executed, he writes:—

"According to Haughten, saponite occurs with serpentine in Cornwall. Some specimens I collected there I take to be the same mineral; but it is not 'soft like butter or cheese,'—it is hard, something like

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serpentine, and may be actually a white or cream-coloured serpentine. The specimen laid by for you will settle the point. I should like to see your saponite."

This sentence led me to compare the specimens which I have of what I have called the "super-hydrated vein-serpentine" with the descriptions of saponite given by Dana,—and my analyses of these specimens with the column of analyses to be found at page 472 of his work.

While the physical properties assigned to saponite by Dana agree perfectly with those of the specimens which I have analysed, and therefore warrant my assigning the name to the Scotch specimens, it cannot be said that the claim of certain of Dana's specimens to the name is altogether beyond a doubt, and this on account of the most characteristic of the features of the Scotch mineral—namely, the low temperature at which it parts with some of its water—not having been observed in the specimens hitherto ranked as saponite. When, however, the *analyses* given by Dana are considered, there is no room for doubt that some of the substances analysed should not have found a place there, and there is even room for doubt if any but the *thalite* of Owen should.

Nothing, but their having suffered such a loss of water as I have pointed out as likely to occur through exposure to heat during carriage, could entitle us to associate under one name substances varying in their content of water to such an extent as from 10·5 to 20·66 per cent.—a variation which so far explains, though it hardly justifies, Dana's remark, that "analyses give naturally no uniform results for such an amorphous material." Had it been said that the name had been applied to substances which, filling the steam-holes of volcanic rocks, were unquestionably the products of change or degradation,—possibly not always of the same nature, or of the same material,—such a remark might legitimately be made. It is, however, a fairer inference that the analyses give no uniform results, because *different substances* have been included under one name.

And this inference is borne out in a marked manner by a consideration of the peculiar substance which fills the rents in serpentine rocks; and this consideration leaves little or no doubt that the so-called steatite or seifenstein from Cornwall and from all serpentine rocks must be withdrawn from the species, and that the name must, as I have shown above, be in future confined to one of the materials which plug the amygdules or rarely the rents of *igneous rocks*.

The suggestion of Dana's that as, if we suppose the alumina to be
t as *kaolinite*, the rest is a silicate allied to *aphrodite*,—*as if the*

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mineral were a mixture of the two,—I cannot regard as sound, for the two reasons that, according to Dana himself, neither kaolinite nor aphrodite occur in volcanic rocks (nothing of the kind is to be seen in the Scotch ones), and because, as he himself states, kaolinite is not decomposed by acid, while saponite is.

Any admixture "as kaolinite," with a mineral soluble in acid, would after treatment therewith disclose itself by remaining as an insoluble residue.

The features, so far as I have yet attained to the recognition of them, whereby this super-hydrated vein-serpentine can be discriminated from saponite, are the very much smaller amount of its loss of water when heated,—its smaller content of water,—and a peculiar opalescence and girasol appearance, which it presents, when transparent varieties are looked through.

In five analyses of these "vein-serpentines" from Scotland which I have executed, I have found the quantity of total water to lie between 15·16 and 16·58 per cent.; and of this the loss at 212° ranged from 1·63, which was that of the lowest total, to 3·53, which was that of the highest.

The deduction of these losses, it will be observed, brings the residual water to about the amount normal to serpentine.

Such were the conclusions I had arrived at when the receipt of a box of Irish serpentines from Professor King, containing specimens of the "saponite veins" of Cornwall, collected by himself, enabled me by analyses to speak with more precision on the matter.

The specimens of the Cornish "saponite" were at once seen to be physically very similar to the paler-coloured vein-serpentines of Portsoy. Being apparently somewhat weathered they were opaque, and the girasol appearance could not be seen.

A weathered vein from the serpentine of Polmally, in Glen Urquhart, which was very similar, was analysed along with this Cornish saponite.

It is not necessary here to quote more than the content of water, and loss thereof at 212°: this was—

	Total water.	Loss at 212°.
Mineral from Cornwall	14·133	1·166
,, ,, Polmally	15·162	1·626

This, taken in conjunction with a general accordance with their other components, shows that these specimens are similar to other vein-serpentines, and are quite distinct from the mineral which occurs in volcanic rocks.

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As the specimen sent by Professor King is quite similar to other smaller ones which I have seen in the Lizard serpentine, there is every probability that the mineral analysed by Klaproth, Svanberg, and Haughton was the same; and that of the substances classed under the head of saponite by Dana, only those narrated as filling geodes in volcanic rocks properly fall under the title.

Supplement to Chlorite.

I have lately observed what I believe to be a chloritic mud occurring in a form in which it bears a great resemblance to glauconite.

The circumstances of its occurrence are of much interest, and the explanation of these circumstances is attended with no small amount of difficulty.

Immediately to the north of the village of Callander there is a cliff of conglomerate of the Old Red Sandstone; this is here formed of nodules, from the size of a walnut to that of the fist, of gneiss, mica slate, and quartz,—rocks of the immediate neighbourhood.

Rarely, thin interstrata of a finer almost of a sandy grain,—more fitted for building purposes,—occur to the north-eastward of the village.

In several small quarries, opened with a view to work these gritty beds, the characters of the conglomerate may be studied. It has somewhat of a vitrified aspect, and is more broken up by "backs" and "cutters" than is usual to that rock. The dip is to the north-east; the backs run along the strike at distances of about six feet from each other; while the cutters, lying generally at right angles thereto, are much more closely adjacent to each other.

The backs, in those cases in which they have stood open, are invariably filled with one of the varieties of the substance to which the names of *reddle*, or *keely* or *keels* has been attached: the cutters are as invariably lined, and usually no more than lined, on each side with sheets of cockscomb barytes, which sometimes carry vitreous copper, malachite, and calcite.

The dull red of the vertical sheets of reddle is everywhere besprinkled with spots and blotches of a vivid green, of the colour of glauconite,—these spots are circular in form, or consist of a number of confluent circles, each circle being of about the size of a large bean.

The contrast of these colours is so striking as to arrest the attention of the passer-by; it is found upon examination to be due to the occurrence in the pseudo-vein of reddle, of "concretions" of granular pale purple carbonate of lime, of a discoid form; and to these concretions

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being invested by the glauconite-like material, disposed in a laminated manner.

Portions of the calcareous concretions,—of their green coating,—and of the reddle, were examined in the laboratory, after isolation each from the others.

The concretions did not appear to have any structural arrangement of particles, being similar to a very fine-grained saccharine marble; they dissolved readily and totally in acid, without leaving any save a glauconitic residue; and neither they nor their associates contained any trace of baryta.

The glauconite-like matter was found to be insoluble in all acids; but after treatment therewith and agitation in much water, it separated into minute colourless pearly scales (like mica), and a green powder, which was also minutely scaly.

The reddle had a laminated arrangement of its particles parallel to the sides of the vein; it resembled a red sandy clay, and glistened with minute scales of mica. Treated with chlorhydric acid it yielded readily a ferruginous solution, but left behind the greater part of its bulk as a green powder, similar in appearance, and also in its insolubility similar to that which presented itself originally with a green hue.

From the evident admixture of scales of mica, it may be doubted if an analysis of these green powders — probably identical — would definitely disclose their nature; but the above chemical features sufficiently show that they cannot be any one of the saponites, unless it be celadonite, and their being the latter is contradicted by their scaly structure.

Their insolubility in acids equally proves that they cannot be glauconite; and, having regard to the occurrence in the conglomerate of quartz nodules with a chlorite which is very similar to that of Cruach Ardran and the hills surrounding it, there is every probability that the green portion consists of chlorite alone.

While the impurity of this substance prevents a more accurate determination, enough has probably been attained to, in the direction of indicating several points of marked interest connected therewith.

The following questions present themselves for being answered:—

By what process were these veins filled? The ready reply,—neither by infiltration nor injection, but by exfiltration,—goes but a little way. Conglomerated rocks are more pervaded by a system of *inosculating holes* than by fissures,—but I broke many pieces of the rock without being able to detect in its cavities any green matter in the course of

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being transported to its resting place in the vertical rents; but an exfiltration of reddle-like matter may be observed, and this may obscure a concomitant chloritic transfusion.

Then, *What is the action whereby the segregating calcareous matter repels the hematitic*,—thus operating as a pseudo-bleacher?

And lastly, *How comes it that the one set of rents are lined with baryte, with vacuous interspaces; while that which lies at right angles thereto contains no trace of baryte, but is totally filled with a clay-like material?*

An explanation which may be said to lie upon the surface—namely, that the first mentioned set had been of earlier formation, and had been the seat of a process which had reached its termination before the formation and filling up of the latter,—does not meet the facts of the case, because the rock-rents which form the "backs" seem to have been antecedent to those existing as "cutters"; for the former pass numbers of the latter, while these but very seldom cut across the former.

The rock seems to be *still* purveying hematitic and chloritic matter to the cracks which form its "faces";—*is there a polarity in the guidance of its decomposition*, acting so as to fill its minor and secondary rents with barytes and with copper,—enabling them at the same time to reject the slimy plug which chokes the backs, that they may at least aspire to the dignity of being true mineral veins?

Some questions of weighty mining import might possibly be answered through a study of this narrow field;—the points of chief mineralogical interest are the occurrence of a chloritic mud in a form simulating glauconite,—and the singular manner in which a large quantity of chlorite may be entirely masked by a comparatively small quantity of peroxide of iron."

REINITE (*Neues Jahrb.* 1879, *Heft*, 3, 4. *page* 286 *oder Zeitschrift f. der NaturwissenSchaften in die Provinz. Sachsen und Thuring.* 1879, has been so named by K. von Fritsch after its discoverer Professor Rein, who found it at Rei Japan; it has been described by O. Luedecke. Reinite occurs with large contemporaneously formed quartz crystals, of which many exhibit a beautiful fracture according to + R. For investigation one large crystal was employed: form tetragonal, the fundamental pyramid (111), whose polar angles were very slightly truncated by the pyramid of the second order (101). The appearance of large sub-crystals with the axis inclined to the chief crystal is frequent. The polar angle (111) : ($1\bar{1}1$) is 103 32′. The relation of the axis $a : c$ is as 1 : 1·79: the angle (111) : (101) was

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measured as 141° 15′—14° 30′ with the hand goniometer. H=4, Sp. Gr.=6·640; cleavage imperfect (110); fracture uneven; color dark-brown; streak brown; lustre vitreous-metallic; opaque. Before the blowpipe behaves itself according to N. H. Rose, like a Wolfram containing a large amount of iron. H Cl, HNO_3, and H_2SO_4, do not decompose the tungstate of iron even when boiling.

Composition according to E. Schmidt:—

Ferrous Oxide	24·33
Tungstic Acid	75·47
Lime	a trace
Maguesia	,,
Tantalic Acid	,,

Reinite is therefore pure tungstate of iron with the formula $FeWO_4$ and is connected in its chemical relations with Hübnerite and Wolfram. As tungstate of iron and tungstate of manganese both crystallise in monoclinic forms, so their simple union must also be monoclinic, which is the form assumed by Hübnerite. As also the tungstate of iron, as Reinite has arranged itself in five symmetrical planes, so it is to be assumed with every probability that the tungstate of iron as well as the tungstate of manganese are isodomorphous.

T. A.

HELDBURGITE.—(*Zeitschrift für die gesammten Naturwissen Schaften Bd.*, II, *Heft* 2, *page* 291, 1879.)—In the felspar of the Phonolite of Heldburg in Coburg, O Luedecke discovered a few fragments of minute columns associated apparently with Zircon, the largest of which was 3 mm. long, ½mm.—½mm. thick. Crystalline system tetragonal: Combination of (110) (100) (111.)

Values the of following angles were measured and calculated:—

	Measured.	Calculated.		Difference.
$(1\bar{1}1) : (\bar{1}11)$ ..	86° 40′ 8	86° 37′ 5	+	3′ 3
$(\bar{1}11) : (\bar{1}10)$ ..	136° 37′ 5	136° 41′ 2	—	3′ 7
$(\bar{1}10) : (\bar{1}1\bar{1})$ ..	136° 44′ 1	136° 41′ 2	+	3′ 9

The relation of the axis *a* to the principal axis $c=1 : 0{\cdot}7500$, or as 4 : 3, measurements approach those of Zircon and Oerstedite. External characters resemble those of Guarinite. Hardness less than steel; color yellow; streak white; adamantine lustre; transparent; before the blowpipe infusible; chemical composition unknown; titanic acid absent.

T. A.

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HERRENGRUNDITE.—[*Urvölgyite.*]—*Min. und Pet. Mitt. Tschermak : Band II, Heft III and IV, p.* 311—324.)—This hydrated cupreous sulphate of lime, from Herrengrund (Hungary) was briefly referred to in the last number of the Mineralogical Magazine. It occurs in an unworked part of the copper mines of Herrengrund (Urvölgy) near New Sohl in the N.W. of Hungary. It was at first taken for Brochantite and for Langite.

Morphological relations :—The mineral forms laminated groups, dark-green to bluish in colour, upon a yellow-quartz conglomerate. These groups are so symmetrical that they present ball-like aggregates with rough surfaces and dark-green satin-like lustre. Single crystals do not occur: but the lamellæ can be examined separateiy, and shew striking parallel lines which at their terminations experience a truncation, at their sides a bevelling. With the plane of the lamellæ the truncated surfaces form right angles, with each other an angle of 130° approximately. Cryst. system Rhombic,the parallel lines correspond to the brachydiagonal; plane of the lamellæ, the basal pinakoid OP : the two truncated surfaces which touch in the brachy-diagonal are the prism surfaces ∞P ; whilst the bevelled surfaces represent the brachydome $P\breve{\infty}$. In this way the combination 0P, ∞P, $mP\bar{\infty}$ is formed. According to Schafarzik the angles 0P : $mP\breve{\infty} = 130—131°$; $mP\breve{\infty}$ 102°. According to Winkler the angle 0P: $P\breve{\infty} = 130\frac{1}{2}—131°$. Besides the surfaces in this dome another surface appears without a corresponding one on the opposite side, which gives to the combination a monoclinic aspect, though the cause of the defect is dependent not on the imperfection of the developement, but is produced by unequal central distance. According to Dr. Brezina however, the crystalline system is monoclinic with a slight angle.

Elements : a : b : c=1·8161 : 1 : 2·8004, $\beta = 91° 9' 5''$.

Optical relations: In revolving the Nicol very much dichroism—bluish-green, greenish-yellow. With the crossed Nicols the maximum of extinction occurs in the direction of the parallel lines: if a thicker lamina be taken, an axis image appears on the plane, consequently the mineral is biaxial, the axis lying in the plane of the brachydiagonal section : axis angle great: both images perfectly symmetrical: dispersion of optical axis $\rho < v$. The bisection occurs with the principal axis, and consequently the optical peculiarities favour the view that it belongs to the rhombic system. With polarised light the thin plates shew strikingly those colours conditioning dichroism: thicker plates on the contrary shew a lively play of colors, and from these experiments it is evident twinning frequently occurs—the twin planes being parallel with the brachydiagonal.

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Lustre and color.—Both are of two kinds, vitreous, and mother of pearl like : dark emerald-green to a bluish sea-green. Glassy lustre at peripheral surfaces, and in those of the less bent laminated aggregates occasionally a peculiar coppery lustre. Plane 0P seen obliquely shows a mother of pearl lustre ; whilst on a thin lamina it is vitreous At the peripheral surfaces dark-green ; in the plane of the laminæ a blue to light-green colour, but some varieties have only a uniform dull greenish-blue colour.

Cleavage.—In three directions, most perfect in the plane of lamellæ, and if heated this takes place in thinner leaves also. Cleavable in the direction of the brachy-diagonal. When rubbed between the fingers it breaks up in this plane, and in rare cases cleavage is seen parallel to the surfaces of the prism. Cleavage accordingly 0P perfect; $\infty P\infty$ perfect; ∞P imperfect. Hardness 2·5—3 ; density 3·132 (Winkler.)

Composition :—

H_2O	16·726
CuO	42·520
CaO	8·587
$S O_3$	24·620
SiO_2	0·332
FeO	0·142
Mn. Mg	(traces)
	99·927

Position in the mineral system:—It must be placed near Brochantite, Langite, Linarite, and Cyanotrichite, but it is most closely allied to the first two, as indicated by the physico-chemical distinctions now to be spoken of. Brochantite in powder under the microscope always appears green without a trace of blue ; Langite on the contrary pure blue, thicker masses deep blue, thinner azure blue, at the most with a shade of green. Herrengrundite in thick fragments is emerald-green, yet never possessing the intensity of Brochantite ; in thinner layers it is greenish-blue. It is distinguished, however, by its chemical relations. By the wet method, all three are soluble in HNO_3 and give with excess of ammonia an azure-blue solution, in which a drop of oxalic acid produces a white precipitate with Herrengrundite, but none with Brochantite or Langite. The flame reactions are still more characteristic, Brochantite and Langite give only the blue-copper flame, whilst Herrengrundite gives both the yellowish-red lime flame and the blue copper flame. Cleavage of Brochantite under the microscope has been observed in three directions. In Langite the optical axes lie in the brachy-diagonal section ;

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the observed combinations nearly agree; the three species are thus very nearly allied.

Paragenetic relations :—Herrengrundite about 1 mm thick is found covering a bed of finely granular white gypsum, and is of two kinds—an earlier and a later formation; the later is a dark-green, strongly shining mineral, its normal condition—the older is dullish-blue, and appears to be covered with a white powder. The occurrence of the mineral with gypsum is significant, but still does not appear to suffice for the formation of the cupreous sulphate of lime. Here this hydrated sulphate of copper and the constituent parts of gypsum have crystallized together in such a way that the Brochantite or Langite substance maintains a preponderating influence, and thus maintains also the rhombic type. On the other hand if, according to Prof. Schenck we group the molecular relations as 6 H_2O, 4 CuO, 2 SO_3, 1 CaO, next withdraw a molecule of gypsum (CaO, SO_3 + 2 H_2O) the remainder may be combined in the following way, 3 CuO, SO_3 + CuO H_2O + 3 H_2O, a formula showing that Herrengrundite is more nearly allied to Langite than Brochantite. A fact still more clearly brought out is the composition of Herrengrundite, from which it may be considered that a molecule of Langite and a molecule of gypsum have crystallised together, which may take place with the basic hydrated sulphate of copper on separating from a water containing gypsum. From the experiments of Schenck of Schemnitz, it appears that the gypsum of Herrengrundite dissolves in 3000 parts of water, *the water of crystallization of Brochantite, and only a very small quantity of Brochantite.* The question now arises here is the Gypsum and Brochantite contained in Herrengrundite. Is it a mixture or a double salt? In favour of its being a double salt the fact exists that the percentage of sulphuric acid goes half to the gypsum and half to the Brochantite. Investigations also evidently show that the mineral is to be regarded as a product of the crystallizing together of gypsum and a substance like Brochantite or Langite, exhibiting at the same time its easy decomposition and mode of dissociation under the action of water and dilute muriatic acid. In all chemical experiments also the individual peculiarities of gypsum and Brochantite always appear: then the striking peculiarity is seen, that nitric acid dissolves the Herrengrundite without a gypsum precipitate, whilst muriatic acid does not: the explanation being that the nitric acid is a better solvent of gypsum than the muriatic. But both hydrated snlphates manifest a strong tendency to crystallise together, which in different relations can take place apparently in varying pro-
---tions—the green color being more connected with the Brochantite,
emical composition and optical peculiarities with the Langite.

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From further investigations into the occurrence of these hydrated carbonates of copper, the paragenetic relations may be stated as follows, commencing with the youngest member:—1st α *Herrengrundite* bright shining emerald-green, forming considerable masses. β *Herrengrundite* dull bluish-green substance, similarly grouped aggregates formed of minute laminæ. *Azurite* forms single granules. *Malachite* as a botryoidal crust of fibrous structure. *Pitticite* amorphous, blood-red, very rare. *Gypsum*, short white fibres, in rare instances forming layers from 10-12 mm. thick.

Herrengrundite is derived from tetrahedrite and chalcopyrite, both of which occur in layers in scattered patches in the quartz conglomerate of the district. It has also been found at Erbstollen, in small amount. At the depth of a metre below it water was found. Herrengrundite has also been seen directly in contact with coarse tetrahedrite, though it is usually found upon gypsum or malachite.

The veins at Herrengrund occur in grauwacke and mica schist, the latter being the under, the former the upper layer, above which a triassic limestone is met with, in which the veins show no continuation, though it may have supplied the lime for the formation of the gypsum.

T. A.

On a New Process for the Microscopic Study of very Minute Crystalline Grains (M. J. Thoulet, *Bull. d. l Soc. Min. d. France, II*, 7).—The author embeds the particles of mineral in a cement, which, when set, he slices and polishes for microscopic examination. The mineral powder, to be examined, is mixed with ten times its volume of oxide of zinc, and enough silicate of soda (or preferably, of potash) is added to make a thick paste. This paste is then transferred to a mould, made by laying a thin ring of glass upon a sheet of paper. In a few days the mass will have set hard, and can be removed from the mould, ground, and polished like a natural rock, as it possesses great tenacity. On examination under the microscope, the sections of mineral that it contains are easily distinguished in the midst of the surrounding opaque material.

H. L.

On a New Process for taking the Specific Gravity of a Mineral in Minute Grains (M. J. Thoulet, *Bull. d. l. Soc., Min. d. France. II*, 7).—The first stage of this process is the preparation of a float of wax, containing a minute fragment of some mineral, so that the sp. gr. of the whole shall be between 1 and 2; the author employs a splinter of orthoclase and surrounds it with wax, till it forms a mass of about the

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size and shape of a grain of wheat, which has then to be carefully weighed. The fragment or fragments, whose sp. gr. is to be taken, and the weight of which is exactly known, are attached to the float by a gentle pressure of the fingers. The whole is then immersed in a solution of iodide of mercury in potassic iodide, and the solution is gradually diluted with water until it has exactly the same sp. gr. as the float, which may be known by the latter neither rising nor sinking in the solution. The sp. gr. of the solution is now taken; let it equal Δ. The float is taken out of the solution, washed, and the fragments of mineral carefully removed with a forceps. The float is returned to the solution and water is added, till the sp. gr. of the float and solution are again equalised. The sp. gr. of the solution is then once more determined; let it equal D. Then P being the weight, V the volume, and D the sp. gr. of the float,

$$V = \frac{P}{D}$$

If p be the weight, v the volume, and d the sp. gr. of the mineral,

$$v = \frac{p}{d}$$

and Δ being the sp. gr. of the float with the mineral attached,

$$\Delta = \frac{P + p}{V + v} = \frac{P + p}{v + \frac{p}{d}}$$

$$\text{whence } d = \frac{p\,\Delta}{P + p - \Delta V}$$

H. L.

ON A NEW MINERAL SPECIES, DISCOVERED IN THE DISTRICT OF GUEJAR, SIERRA NEVADA (M. E. CUMENGE, *Bull. d. l. Soc., Min. d. France, II*, 7).—This mineral, which has been named Guejarite by the discoverer, occurs well crystallised in a veinlet of spathic iron ore. The following is its analysis :—

Sulphur	25·
Antimony	58·5
Copper	15·5
Iron	0·5
Lead	traces.
	99·5

These figures correspond to the formula $2\,Sb_2\,S_3$, $Cu_2\,S$, the small quantity of iron found being due to a slight admixture of copper pyrites.

The mineral occurs in brilliant crystalline plates, 20 mm. long and 7 mm. broad; its color is steel-grey; sp. gr. 5·03; hardness 3·5.

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M. C. Friedel has investigated the crystallisation of Guejarite. He finds that it belongs to the rhombic system. The prism (100) is the predominating form, a distinct cleavage being parallel to it; numerous other prisms, several brachydomes and the basal plane (001) also occur. The angle (110) ($\bar{1}10$)=101° 9′ 12″, and the relation between the parameters is—

$$h : D : d = 0{\cdot}7841 : 1 : 0{\cdot}8220.$$

Guejarite is thus isomorphous with Wolfsbergite ($Sb_2 S_3$, $Cu_2 S$) in which species the angle (110) ($\bar{1}10$)=109°.

H. L.

On the Microscopic Examination of some Natural and Artificial Spinels (M. J. Thoulet, *Bull. d. l. Soc., Min. d. France, II*, 8.)—The following is a list of the spinels examined by the author:—Artificial spinels, for the most part prepared by Ebelmen: chromite, chromite of manganese, chromite of magnesia, chromite of zinc, chromite of lime and glucina, ferrite of zinc, ferrite of magnesia, hausmannite, aluminate of iron, zinciferous spinel, and aluminate of zinc.

Natural spinels: Chrome iron-ore, hercynite, automolite, creittonite, franklinite, and pleonaste.

Each specimen was examined under the microscope, its specific gravity taken whenever possible, and its magnetic powers noted; the following are the chief conclusions thus arrived at by the author.

(1.) The greater the amount of iron in a spinel, the less is its transparency.

(2) All spinels, when reduced to the thickness usual for microscopic observations are transparent or translucent, except magnetite, which is entirely opaque; thus hercynite, franklinite, hausmannite, creittonite, and chromite are translucent, though stated by Dana to be opaque.

(3.) All spinels have under the microscope a shagreen-like surface, and this character is more clearly marked the greater the hardness of the mineral; this rough surface does not appear in quartz and in substances softer than quartz.

(4.) No chrome iron or chromite is magnetic; such specimens as show magnetism, owe this property to an admixture of opaque grains, which appear to be magnetite.

(5.) The natural spinels known as hercynite, creittonite, and gahnite, are more or less mixed with oxide of iron; this explains the varying proportions of iron found in different analyses.

(6.) Ebelmen has remarked that in preparing artificial chrome spinels, the crystals first formed are the most strongly coloured by

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chromic-oxide. The microscopic examination of chrome iron-ore confirms this observation, showing ferriferous grains, more or less opaque, agglomerated round the translucent yellow ones; a kind of liquation of the material richest in chromium has taken place, this being first isolated and surrounded by a series of minerals richer in iron, and terminated by magnetite.

(7.) The anisotropic action of the chromite of glucina and lime, closely related to the polarising properties of cymophane or aluminate of glucina gives support to the theories which tend to show that glucina is a sesquioxide.

H. L.

ON THE DEHYDRATION-ELLIPSOIDS OF RHOMBOHEDRIC CRYSTALS (*L Schncke, Zeitsch, f. Kryst., u. Min., P. Groth, IV*, 3).—According to some experiments made long ago by Mr. Pape, when a crystal, into the composition of which water enters, is heated, spots of decomposition (dehydration) are formed on the various planes, which spots generally shew an elliptical outline, being in fact such figures as are produced by the intersections of the respective planes with an ellipsoid which is characteristic of each crystalline body, and occupies a constant position with reference to the axes of the crystal. Supposing the decomposition to start from the centre of the crystal, it will usually extend with unequal rapidity in different directions, the surface of the dehydrated portion forming at each moment an ellipsoid, the dehydration ellipsoid. This behaviour corresponds to that of the conductivity for heat, and of several other properties of crystals, each of which may be represented by the radii vectores of an ellipsoid as a function of the direction. But Mr. Pape has observed one startling difference, namely that in rhombohedric crystals the dehydration-ellipsoid is a sphere, whilst the other properties are represented by ellipsoids of rotation, the axis of rotation being parallel to the main axis. These observations were made on three substances :—

Plumbic dithionate	($Pb S_2 O_6 + 4$ aq.)
Strontic dithionate	($Sr S_2 O_6 + 4$ aq.)
Calcic dithionate	($Ca S_2 O_6 + 4$ aq.)

The author of this paper has re-examined the results obtained by Mr. Pape, and, after very numerous observations, finds that the surface of dehydration of the above-named rhombohedric salts is not a sphere, but is a very close approximation to an ellipsoid of rotation. The method of experimenting was the following :—The crystals were heated in a hot air bath, and as soon as small spots of dehydration (usually between 0·02 and 0 04 mm. in diameter) were produced, the

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crystals were removed, and the major and minor axes of the ellipses measured by means of a micrometer. The author gives at length the numerical results obtained, and finds therefrom that the first-named salt has an elongated dehydration-ellipsoid, the ratio of the vertical to the horizontal axes being 11:10, whilst the two latter salts have a compressed dehydration-ellipsoid, the ratio of the axes being approximately 10:12.

H. L.

ON SERICITE (*H. Laspeyeres, Zeitsch. f. Kryst. u. Min., P. Groth, IV*, 3).—Numerous authorities have attempted to show that Sericite is a separate mineral species, but the author of this paper contends that it is merely a massive potash mica He analysed it by boiling the finely divided mineral for several hours a day during 5 months in pure hydrochloric acid; 19·021 per cent. was left unattacked, being principally quartz, and the decomposed mineral was found to contain—

Silica	45·361
Alumina	32·919
Ferric Oxide	2·048
Ferrous Oxide	1·762
Lime	0·494
Magnesia	0·895
Potash	11 671
Soda	0·724
Water	4·126
	100·000

The composition agrees well with that of a potash mica, and this view of the constitution of Sericite is moreover supported by a careful examination of the physical properties of the mineral.

H. L.

ON ARSENIATES FROM THE JOACHIMSTHAL (A. SCHRAUF, *Zeitsch. f. Kryst., u. Min., P. Groth, IV*, 3)—*Mixite* a new hydrated arseniate of copper and bismuth. This mineral occurs in the so-called "Geistergang," at a depth of 20 metres, and was found by Mr. A. Mixa. Its mineralogical characteristics are as follows:—Color, emerald-green to bluish-green, streak somewhat paler; hardness 3-4; sp. gr. 2·66; the most delicate fibres are almost transparent. The mineral occurs as an efflorescence on impure yellow bismuth ochre; in scattered grains; and in spherical reniform aggregations, granular in the centre, and concentrically fibrous towards the exterior, the fibres appearing under the microscope as six-sided prisms. The angle of the prism is about

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55°, and as the direction of maximum extinction is inclined 6°—9° to the edges of the prism, the crystalline system must be monoclinic or triclinic.

The mineral is easily recognised by its behaviour towards dilute nitric acid; when immersed in it, it is immediately covered with a film of a brilliant white powder of arseniate of bismuth, while the arseniate of copper enters into solution. The mean of three analyses gave:

Cu O	43·21
Fe O	1·52
Ca O	0·83
$Bi_2 O_3$	13·07
$As_2 O_5$	29·40
$P_2 O_5$	1·05
$H_2 O$	11·07
	100·15

The formula corresponding to this composition is Cu_{20}, Bi_2, As_{10}, H_{44}, O_{70}, which may be rationalised thus:—

$$\begin{cases} 4\,(Cu_3\,As_2\,O_8 + 2\,Cu\,(HO)_2 + 3\,H_2O) \\ +(Bi_2\,As_2\,O_8 + 2\,H_2O) \end{cases}$$

The minerals that accompany mixite are various species of decomposed bismuth ores and Tennantite, mostly somewhat decomposed and containing some bismuth; chalcolite and bismuthite also occur with it.

Wapplerite. The author gives a long series of goniometric measurements of this mineral, which justifies the assumption of the following system of parameters:

$$a : b : c = 1 : 1{\cdot}11002 : 0{\cdot}29037$$
$$\alpha = 90°\ 13'\ 55'' \quad \beta = 95°\ 20' \quad \gamma = 90°\ 10'\ 35''$$

Good crystals shew a very close approach to monosymmetry, which may be induced to some extent by twinning.

Wapplerite is distinguished optically by showing "dispersion croisée," the arrangement of the colors being the opposite to that which obtains in the case of borax.

Pharmacolite. In addition to the planes already known to occur in this mineral, the author has observed the pyramid $(11\bar{1})$; he gives a list of goniometric measurements of some crystals, and compares the angles found with those calculated, taking the following system of parameters: $a : b : c = 0{\cdot}61373 : 1 : 0{\cdot}36223$, $\beta = 96°\ 46'\ 6''$. The results obtained are fairly concordant.

H. L.

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DAVREUXITE (M. L. L. de KONINCK, *Bull. de l' Acad. roy. d. Belg.* (2) 46 *No.* 8, *August*, 1878; *Zeitsch. f. Kryst. u. Min., P. Groth., IV*, 1).—This mineral was first found by Dumont in quartz veins in the slates of the Ardennes at Ottré, but was mistaken for asbestos; the author has found it in small quantities at Sart-close (Salm-Chateau.) It consists of very thin transparent needles, white to flesh-colored, sometimes containing a little admixed quartz. It is infusible in the Bunsen flame, and but slightly attacked by acids. The following is the mean of three analyses:

H_2O	4·19
SiO_2	55·94
Al_2O_3	33·59
MnO	5·25
MgO	1·10
	100·07

Traces of iron present.

The author estimates that $\frac{1}{6}$ of the material analysed consisted of quartz, and therefore subtracts 16·63 per cent. from the SiO_2 found by analysis. He thus obtains for Davreuxite the formula H_4 (Mn. Mg.) $Al_6 Si_6 O_{18}$*

H. L.

ON A NEW RESIN FROM KÖFLACH IN STEIERMARK (BY C. DÖLTER, *Mitth. d. naturwiss. Vereins f. Steiermark*, 1878; *Zeitsch. f. Kryst. u. Min., P. Groth, IV*, 1.)—This resin occurs in layers about 1 inch in thickness in the Tertiary lignites at Lankowitz; color dark-brown; thin splinters reddish-brown, translucent; fracture conchoidal; sp. gr. 1·2—1·25. Soluble in ether and carbon disulphide, insoluble in alcohol and in caustic potash.

Analysis after subtracting 1·90 per cent. of ash:—

C	82·23
H	10·28
O	7·49
	100·00

Formula $C_{30} H_{48} O_2$. Melting point 98°, but the resin softens at a far lower temperature. Electric on friction. This resin is hence a retinite closely related to Jaulingite.

H. L.

* Thus in the German original the formula should read H_4 (Mn., Mg.) $Al_6 Si_6 O_{24}$.

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NOTES ON MINERALS (A. VON LASAULX, *Zeitsch. f. Kryst. u. Min.*, *P. Groth, IV*, 2).—*Titanomorphite*—Amongst the gneissic rocks that form the crest of the "Hohe Eule" (in Silesia) there are numerous hornblendic rocks, some of which are so rich in garnets, that they may be called garnet-amphiboles. In a quarry of this rock there occur numerous nodules of rutile, varying from microscopic size up to that of a nut; each rounded nodule, composed at times of several closely coherent grains, is surrounded by a pale greenish white zone of a finely fibrous structure, the fibres being arranged radially and normal to the exterior surface, on approaching which they gradually assume a granular structure. The rutile nodules but rarely shew their characteristic brownish-red color; they are often quite black like Ilmenite, and contain an ochre-yellow kernel of rutile; they are of the variety of rutile known as nigrine, and consist, as has already been pointed out by Rammelsberg, of a mixture of Ilmenite with rutile. The thickness of the crusts of Ilmenite round the kernels of rutile is variable, and some specimens contain no kernels at all. All, however, are surrounded by the white substance above-mentioned, but in varying quantities. This substance has been referred erroneously to various mineral species, but the author has long supposed it to be a titanate of lime, and has named it Titanomorphite.

Titanomorphite forms as already stated granular fibrous aggregates, but even the minutest fibres are composed of rows of distinct granules. By means of exhaustive optical observations made on sections through some of the larger granules, the crystalline form of the mineral has been determined with some certainty. The mineral is biaxial and highly double refracting; it is optically positive; dispersion of the axes very strong; 2 E=45°—50°; thus agreeing very closely with the optical properties of Titanite; it is therefore monoclinic.

The following are the values of the principal angles in

	Titanite.	Titanomorphite.
$(001/\bar{1}02)$ ..	39° 17′	40°
(001/110) ..	85° 45′	86½°
$(\bar{1}02/10\bar{1})$ ..	21°	19°—20°
$(10\bar{1}/110)$ ..	40° 34′	41½°
(110/110) ..	46° 8′	45°—47°
(123/123) ..	43° 48′	43°—45°

These figures shew a very close isomorphism between the two minerals.

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The following is an analysis of Titanomorphite, made by Dr. Bettendorff :—

TiO_2	..	74·32
CaO	..	52·27
FeO	..	trace.
		99·59

This composition agrees well with the formula $CaO, 2\ TiO_2$; so that titanomorphite is not only physically and optically isomorphous with titanite, but their chemical compositions also correspond.

Titanite	$Ca\ Si_2\ O_5 + Ca\ Ti_2\ O_5$
Titanomorphite	$Ca\ Ti_2\ O_5 + Ca\ Ti_2\ O_5$

thus affording a fresh instance of the isomorphism of titanic and silicic acids.

Idocrase from Gleinitz and from the Johnsberg, near Jordansmühl (Silesia).—Idocrase, forming incrustations of a yellow or peach-blossom color, has long been known to occur on a decomposed mica-schist on the south-eastern side of the Johnsberg; the idocrase of Gleinitz similarly forms layers 1—2 inches thick, in serpentine, which layers consist of columnar aggregates with well-developed crystals projecting into the cavities. These crystals are colorless or pale-greenish, rose and amethyst-colored; the latter color is, however, never spread over the whole crystal, but is confined to the polar extremities. The other varieties only shew a feeble dichroism, but the amethystine portions are strongly dichroic, being pale-green in the direction *c*, and peach blossom-colored along *a*.

When a section perpendicular to the axis is examined in parallel polarised light, the phenomena that have been described by Mallard appear, the square plane being divided into four equal, triangular segments; in convergent polarised light the crystals are seen to be uniaxial. Sections parallel to the axis shew that the crystal consists of thin concentric layers. In this case the anomalous behaviour towards light is a sign, not of a pseudosymmetrical crystalline form, but of an anomalous mode of growth of the crystals.

The following forms have been observed in the well-developed crystals :—

(1) ∞P (110), $\infty P\infty$ (100) P (111) $P\infty$ (101) o P (001) and $\infty P\,2$ (120); the ordinary form of Idocrase from Wilni.

(2) Prisms predominating; prisms and a ditetragonal pyramid (3 P 3) alone occur; rarely P, never oP.

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(3) Pyramids predominating, prisms scarcely developed at all; only P, P∞ and oP occur. This is a very rare form.

The peach-blossom colored crystals from the Johnsberg are always of the first type.

The following are analyses of two samples by the author, No. 1 being that of the colorless crystals from Gleinitz, and No. II of the peach-blossom colored crystals from the Johnsberg.

	I.	II.
SiO_2	37·57	37·32
Al_2O_3	16·30	16 87
Fe_2O_3	1·82	2·57
FeO	2·76	2·38
CaO	36·26	34·46
MgO	1·75	0·67
MnO	—	3·23
Na_2O	not determined	—
H_2O	3·01	2·22
	99·47	99 72

It thus appears that the red tinge of the Johnsberg crystals is due to MnO, and this variety may therefore be designated a manganese-idocrase.

Gismondine from the basalt of Schlauroth near Görlitz. The author has undertaken an elaborate optical examination of some small pseudo-quadratic crystals, obtained from a geode in the above basalt. As the planes of the crystals did not exceed 2—3 mm. in length, and were too imperfect for goniometric measurement, optical examination had to be resorted to, to determine the crystalline system of the mineral. Sections parallel to the pseudo-quadratic base, parallel to an edge, and parallel to a diagonal of this base were examined.

Although the author has been unable to determine the ratios of the parameters, he has succeeded in arriving at the following conclusions: All crystals of Gismondine are twins of asymmetrical individuals, which latter consist of combinations of very simple forms; pairs of dome planes, and quarter pyramids, either by themselves or combined with the former. The twins are either simple interpenetration twins formed in accordance with the law: "twin-plane a brachydome," or else double twins obeying the above law, and the following: "twin-plane a macro-diagonal section." As the relations of the axes approach very nearly to those of orthoaxial symmetry, the twin forms shew pseudo-rhombic or pseudo-quadratic symmetry.

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The interpenetration groups from the Schiffenberg, described by Streng as consisting of six crystals, are thus in reality composed of twelve individuals, and the forms thus produced approximate very nearly to those of the regular system. In respect therefore to the mode of twinning, Gismondine evidently corresponds closely with Phillipsite and Harmotome.

The differences and divergencies between the angles of the pseudo-quadratic base, and those of the polar edges are caused by the different inclinations to the vertical axis of the two brachydomes, both of which can be planes of twinning; but more especially by the modes of combination of the planes which form the lateral pseudo-quadratic edges, and which condition their position.

The differences between the angles of Gismondi's Zeagonite are decidedly within the limits of the differences observed in Gismondine, and there is no doubt but that these two minerals should be considered to form only one species.

H. L.

On Perowskite (H. Baumhauer, *Zeitsch. f. Kryst. u. Min., P. Groth. IV*, 2)—The author has investigated the crystalline form of Perowskite from various localities by an examination of the figures produced by etching the planes of the mineral. The re-agents employed were hydrofluoric acid, bisulphate of potash, caustic potash, etc. He finds that perowskite is rhombic, the ratios of the parameters being 1 : 1 : 0·711, the principal planes being ∞P, oP (forming a pseudo-cube) P, $\infty \breve{P} \infty$, $\infty \check{P} \infty$, (forming a pseudo-dodecahedron), and 2 $\breve{P}$ ∞, 2 $\check{P}$ ∞, (forming a pseudo-octahedron). The twins are always extremely complicated, but P and ∞P appear to be the most commonly occurring twin-planes.

H. L.

Crystallogenesis.—(Chevalier Charles de Hauer, *Imp. Geol. Inst., Meeting January 13th*, 1880).—The presence of a small proportion of *Borax* in a solution of *Sulphate of Magnesia* gives rise to uncommonly perfect and completely developed crystals, nearly all of them with hemimorphous terminations. When the proportion of borax is not excessively small, a second pair of planes appears at the pointed extremities, these however are always of very subordinate extension.

The form of the crystals is essentially different according to the proportion of borax in the solution, and becomes apparent by admixture of a very small quantity of this substance. When this proportion is considerable, the crystals of sulphate of magnesia

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become notably harder, assuming the form of very shortened prisms, so that the terminal surfaces nearly touch each other. Such crystals, when adherent by one of their terminal surfaces, have the aspect of tetrahedra, which they keep when allowed to grow up to a considerable size. The crystals, formed in a solution containing much borax, are characterized by a great number of terminal surfaces, especially when grown up to a notable size. Some of them have on one termination no less than eight surfaces. The proportion of borax in the solution being very great, the terminal surfaces of the crystals, instead of being smooth and specular, are covered with hemispherical or circular prominences and shallow serpentine furrows, the prismatic surfaces remaining unaltered. These deformities disappear when the crystals are allowed to continue their growth within a solution containing a lesser proportion of borax.

What has been observed concerning the action of borax, likewise takes place when crystals are growing in a mixture of sulphate and chromate of magnesia, whatever the mutual proportions of these ingredients may be. Mixed solutions of sulphate of magnesia with sulphate of nickel or of cobalt in varied proportions give rise to green or red crystals, identical in form with those of unmixed sulphate of magnesia, and showing, when somewhat increased, all the irregularities and deficiences of their terminations as observed on those of unmixed sulphate of magnesia. The presence of borax acts likewise on the mixed solutions here in question, giving rise to well-developed crystals with hemimorphous terminal surfaces, preserving this charracter during their further increase. This, however, only takes place when in the mixed solutions, the proportion of sulphate of magnesia considerably prevails over that of the sulphates of nickel or cobalt. The addition of borax causing a precipitation of cobalt and nickel, some drops of a free acid must be added to the solution. The episomorphous crystals, arising out of these mixed solutions in variable succession, are beautiful and easily obtained. In some of them, the sulphates of magnesia and nickel, of magnesia and cobalt, of magnesia and the sulphato-chromate of magnesia, are superposed on each other, and the pellucidity of these crystals is such, that the limits of the single strata are distinctly perceptible. The immediate contact of the solution of sulphato-chromate of magnesia with the crystals containing nickel or cobalt, must be avoided, which is done by allowing a stratum of pure sulphate of magnesia to be deposited on the surface of these crystals.

Chlorate and *Bromate of Soda.* The presence of some sulphate of soda in a solution of chlorate of soda provokes the formation of tetra-

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hedral crystals with the angles replaced by three-planes, and subordinate hexahedral surfaces. When a hexahedral crystal of chlorate of soda, with traces of hemihedry, is plunged into a solution of sulphate of soda, it assumes soon the tetrahedral form in the course of its increase. When the proportion of sulphate of soda is considerable, the tetrahedral crystals show no traces of hexahedral surfaces.

Bromate of Soda is only obtained in a regular octahedral form, or in such with somewhat prevalent threefaced octahedral surfaces. A solution of this bromate, mixed with as much of chlorate of soda as it will admit, produces only hexahedral crystals without any indication of hemihedral surfaces. Each of these salts, separately treated, gives *transparent* crystals, while those issuing from a mixture of both, are *opaque* and milk-white.

Crystals in solution of Isomorphous Substances. Saturated saline solutions take up notable quantities of some other salt without regard to their different degrees of solubility. The saturated solution of a salt proves inactive towards the crystals of a substance isomorphous to it, when this last substance is less soluble than the salt contained in the solution. Thus episomorphous crystals may be obained by increase within a solution of an isomorphous substance, while any other crystals disappear when immerged in it.

Dr. Klocke asserts that, having shaken during a long time a crystal of alum, immersed in the saturated solution of a more soluble variety of alum, he observed on the surface of this crystal microscopical etched figures. This fact proves again that crystallization does not proceed according to strict geometrical precision. Dr. Klocke however, goes too far in his conclusions by parallelizing this minimum of solubility with the mutual action of isomorphous salts, and by denying these last to be an exception to the general rule. This assertion would at once annihilate a series of fundamental laws, deduced from experiments and observations, although their geometrically precise concordance with facts cannot be proved.

COUNT M.

SPHERICAL CONCRETIONS. (G. WUNDT., *Imp. Geol. Inst., Meeting March 2nd*, 1880.)—The dark-grey shaly clays of Vils (Tirol), ranked by Gümbel among the "Allgäu" shales (Upper Lias), have proved by their organic remains, collected by the late Prof. Oppel, to be middle Cretaceous, coæval with the Gault.

The clays here in question, intercalated between two zones of Jurassic marble, include spherical concretions, varying from the size of a walnut to that of a fist, grey, with rough surface and uncommonly

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ponderous. They appear very compact and hard, as a compound of sand and cement. Crystalline aggregations form their superficial crust when broken, the transverse section appears grey, compact or fine-grained, occasionally somewhat crystalline and bright, like fine grained dolomite; the centre is generally a coarse crystalline white nucleus, from which occasionally radial fissures proceed to the outer crust. The stratification of the beds including these concretions, is undisturbed, although similar disturbed and upheaved beds likewise include concretions. These last ones being neither crushed nor deformed, they must be inferred to have come to existence subsequently to the violent disturbances undergone by the strata. The uncommon weight of these concretions reminds one of the spheröidal concretions of phosphate of lime in the Cretaceous rocks of Russian Podolia; they are, however, only compounds of carbonate of lime and of gypsum.

COUNT M.

GYMNITE OF PREGRATTEN (TIROL). (CHEVALIER FR. DE HAUER, *Imp. Geol. Inst., Meeting February 17th*, 1880).—This mineral appears under the form of a very thin, earthy, light-green crust, on Serpentine, reminding one of the Gymnite on the surface of chromates of iron from Texas and Alt-Orsova (Croatia). A qualitative analysis manifested the presence of nickel and water, with silica, magnesia, and alumina as accessory constituents, but no trace of cobalt. The gymnite from Pregratten, seems to stand next to the variety from Michipicoten, which, according to Hunt, contains 8 per cent. of alumina; and like this, it is very soft.

The nickel-gymnites of Alt-Orsova, and of N. America appear associated with Chromite; the variety from Pregratten appears as a superficial crust on dark-green serpentine, with granules of magnetic oxide of iron, and with mere traces of chromium. A green mineral ("Emerald-Nickel") had been found long ago at Pregratten, in the form of a crust in the fissures of larger crystals of magnetite, interspersed in decomposed chrysotile. According to Petersen, the oxide of nickel may be derived from the olivine, transformed into serpentine and chrysotile.

COUNT M.

WITHERITE FROM PEGGAU (STYRIA). (M. C. DOELTER, *Imp. Geol. Inst., Meeting March 2nd*, 1880.)—It appears in the form of crystals, rarely exceeding the length of 5 millimeters, on compact Witherite (Carbonate of Baryta), separated from quartzose limestone by bands of brown crystalline sulphuret of zinc. The form of the crystals is P. 2P$\breve{\infty}$ oP, with a somewhat vaulted basis, and depressions on the pyramidal surfaces.

COUNT M.

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Tertiary Eruptives of Schemnitz, Hungary.—*Greenstone Trachytes* (*Propylites*).—(Dr. E. Hussak, *Imp. Geol. Inst.*, meeting March 2nd, 1880).—They are highly decomposed, their fundamental substance is compact, light or dark greenish-grey, interspersed with white decomposed felspar, amphibole, and light-green decomposed pyroxene. Microscopical investigation shows a micro-crystalline structure, greenish amphibole or mica, decomposed into calcite or epidote, highly decomposed plagioclase with abundant particles of calcite, and monoclinous felspar; apatite is scarce, and pyroxene is always wanting. These Trachytes closely resemble the so-called "Ancient Diabasic Porphyries"; they belong, however, decidedly to the Tertiary Eruptives. A variety of them includes pyroxene, decomposed into a viriditic substance, less frequently into calcite or epidote, iron pyrites in abundance and titanate of iron, entire or decomposed. Other varieties include quartz, alone or with pyroxene.

Grey Trachytes (*Amphibolic Andesites*).—They are light-grey, whitish, reddish or brown, with undecomposed vitreous felspar, large prisms of black amphibole and lamellæ of mica. The microscope shows the fundamental substance to be composed almost exclusively of felspar, with a slight proportion of a granular vitreous substance. The unaltered plagioclases include an abundance of vitreous substance, together with prismatic crystals of pyroxene and apatite. Tridymite is not of rare occurrence, titanite is entirely wanting. The amphibolic andesites, like the micaceous ones, include a notable proportion of light-green, very dichröitic pyroxene. One variety has a totally vitreous or sphærolitic brown or uncoloured fundamental substance, abundantly interspersed with brown amphibole, mica, and light-green dichröitic pyroxene.

Dacites (*Andesites with Quartz and Amphibole*).—They are very abundant in pyroxene; their fundamental substance is composed of plagioclase and pyroxene, interspersed with amphibole and mica. The quartz includes a vitreous substance. Another variety is a genuine dacite, whose prevailing components are large fragments of brown amphibole, brown mica, undecomposed plagioclase and irregular granules, including a vitreous substance.

Younger (*Pyroxenic*) *Andesites*.—This variety, formerly ranked among grey trachytes or basalts (*Beudant's* "Trachyte semi-vitreux") has by far the greatest extension in the environs of Schemnitz. They are plagioclase-pyroxenic rocks without any olivine. The fundamental substance consists of interwoven microliths of pyroxene and felspar, either grey or filled with a brown vitreous substance, in which granules of magnetite are abundantly distributed. These microliths are either narrow and lengthened, or short prisms, or rounded. The

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plagioclase is constantly undecomposed, bright, uncommonly abundant in vitreous substances, of distinct zonal structure. The pyroxene, generally undecomposed and light-green, appears in the well-known form of octangular transverse sections, the pinacöids generally prevailing over the prisms; it is highly dichröitic. It is rarely decomposed into viridite or bastite. This last mode of decomposition proceeds from transverse fissures, and is manifested by the formation of green longitudinal fibres. Vitreous substance is included in uncommon abundance; microscopical tridymite and small rounded sphæroliths are of local occurrence. The red rocks, spotted with black, of the Ceykowa Valley, described by Baron Andrian, (*Ann. Imperial Geological Institute*, 1866, p. 396), are genuine pyroxenic andesites, locally penetrated with oxide of iron, which forms a pellicle over nearly every one of the microscopic crystals of pyroxene of the fundamental substance. In this substance, bright black fragments alternate with red ones of euritic appearance. Vitreous substance is abundant; while vitreous felspars and microscopical prisms of black pyroxene are interspersed. The proportion of silica in the rocks here in question varies between 57 and 61 per cent.

COUNT M.

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Correspondence.

A Member writes with reference to Capt. Marshall Hall's query in the last number of the Mineralogical Magazine:—

"As far as the problem is concerned I hardly know what to say. I have enquired after a Bordas circle and find that a number of geodesic instruments of different construction and use go by that name, none of which I have ever come in contact with. A Theodolite could of course be used for measuring crystals, but as there would be no means of centreing or adjusting the crystal, nor any independent axial movement, the measurements would necessarily be cumbersome and inexact. (Either the horizontal or the vertical circle could be used). I do not think it would be advisable to adopt a theodolite for crystallographic work, as the cost of such an alteration would be considerable compared with that of a small goniometer capable of excellent work, and now to be bought for a very small sum."

Obituary.

The Rev. James Clifton Ward, F.G.S., an associate of the Royal School of Mines; formerly an officer of the Geological Survey of England and Wales, one of the original members of the Mineralogical Society and a contributor on several occasions to the pages of the *Magazine*, died at Rydal on the 15th April, aged only 37.

An experienced and energetic field geologist, a fair chemist, a skilled petrologist, a zealous antiquary, an enthusiastic naturalist, a practised lecturer, he was the author of many original papers on geological subjects, more especially relating to Cumberland and Yorkshire.

He will be especially missed in the Lake district, where he had succeeded in overcoming local jealousies among the scientific and antiquarian societies of the county, and in establishing their joint action as the "Cumberland Association."

Short as was his life he has left his mark in the field of Science—and more espeeially in relation to the Lake district, and what may be called Wordsworth's country.

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In David Thomas Ansted, F.R.S., F.G.S., &c., for many years Professor of Geology at King's College, London, the Mineralogical Society has lost another of its original members, who took great interest in its work, but who, from increasing age and infirmities desired to be excused from partaking of its labours.

Professor Ansted was born in London, in February 1814, and died at Melton, Suffolk, on the 20th May, 1880.

As the author of standard works on geology and physical geography Professor Ansted enjoyed a more than European reputation, and in his capacity as Assistant Secretary of the Geological Society, an office which he held for many years, he became personally acquainted with nearly all the geologists of his day.

For some years his work had been chiefly confined to practising as a consulting geologist and mining engineer, and his death leaves a blank which it will not be easy to fill up in the ranks of the professional geologists.

Professor W. H. Miller, F.R.S., the eminent crystallographer was not a member of the Mineralogical Society although he frequently expressed his great interest in its work and progress. He died at Cambridge, on the 20th May, in his eightieth year. His great and important "Treatise on crystallography" now almost universally adopted by crystallographers, was first published in the year 1838.

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VI.—*On Portable Chemical Apparatus for Quantitative Mineral Analysis.*

By A. E. Arnold.

Communicated by J. H. Collins.

TOWARDS the end of the last century one Professor Göttling, who taught chemistry in the schools of Jena, conceived the idea of preparing a portable chest of chemistry, or complete collection of Chemical Tests.* Chemical knowledge being in those days somewhat limited, we are not surprised to find that the contents of the chest could be stowed within a space nine inches square by twelve deep.

This cosmopolitan collection was intended for the use of chemists, physicians, mineralogists, scientific artists, manufacturers, farmers, and the cultivators of natural philosophy. The tests were prepared by a Mr. Hunneman, a friend of the author, and pupil of Klaproth and Hermbstaedt of Berlin; and were put up in thirty five glass bottles and some small wooden boxes.

The tests, such as they are, are in general of a reliable nature, and in accordance with the state of chemistry at that time; but neither chemists,

* A copy of the small treatise which accompanied the collection, and which formerly belonged to Faraday, is now in the Library of the Chemical Society The English version was published in 1791 in London, and was sold by Messrs. C. and G. Kearsleys, No. 46 Fleet Street, who also supplied the chests.

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farmers, nor natural philosophers would derive much practical benefit from their application in this present generation.

The cabinet which I shall presently describe is principally intended for the use of mineralogical chemists, or persons who, having some knowledge of analytical chemistry, are familiar with the appearances presented by the crystalline and non-geometric but distinctive forms, which most common minerals possess. Those minerals also which occur in amorphous masses, in which it is impossible to detect a determinate crystalline shape, but which are technically of the greatest importance, can likewise be usually discriminated by their colour, lustre, hardness, density, &c. It is proposed, if possible, to supply minute directions with the cabinet, by the use of which careful persons, other than these, may arrive at reliable results.

In Professor Göttling's little book, there is no attempt at anything beyond qualitative description. To find out whether a piece of mineral was iron or copper ore, whether a liquid was acid or alkaline, whether a rock was fusible or infusible—these and similar questions are all that it attempted to decide. In fact at that time the attention of scientific men was more bent upon qualitative than quantitative inquiry. To know of what substances the earth is made* occupied their minds more than the question, 'In what proportions are these substances allied to each other?' The discovery that a certain kind of rock contained copper, and that another kind of rock contained lead, were facts of greater significance to them than to us. The merchant and manufacturer now pay little or no attention to such results as these; the information they desire to obtain is of a quantitative character. The percentage of the valuable constituent and the quantity of the deleterious constituent or constituents are the items upon which they calculate. For example, the merchant now guarantees under penalty of forfeit that a cargo of Hematite shall contain at least (say) 55 p.c. of iron and not more than 0·10 p.c. of phosphoric acid, Inasmuch as he knows that all iron ores contain iron and phosphoric acid, a qualitative examination is useless to him. Commercial transactions have been based upon the accurate determination to 0·01 p.c. of iron in a given sample: this it is acknowledged is drawing the line far too fine, but the tendency to scientific exactitude prevalent of late years marks a new era in Commercial Technology.

* Cronstedt's Mineralogy, which appeared in English in 1770, was the first systematic work in this field. He does not give any quantitative relations: neither does he mention in the attached description of a pocket laboratory, any attempt at quantitative estimations. Gustavus von Engestroem and Bergman wrote descriptive treatises upon pocket laboratories soon after Cronstedt's; but the discrimination of different substances occupied their sole attention.

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Notwithstanding the repeated attempts made since Cronstedt's time to produce chemical cabinets which should be of value to the scientific traveller, Plattner was the first to work out* (1853) the means by which a miniature Laboratory of this nature could be rendered capable of performing accurate quantitative determinations. The patience and minute care which he bestowed upon the subject are too well known by members of this society to need mention here. He placed in the hands of chemists and mineralogists a portable cabinet which enabled them to determine the amount of silver, mercury, copper, tin, and iron present in minerals containing them. Of the processes described in his book that for the estimations of silver was capable of giving the most accurate results, and remains a monument of his skilful handicraft. We can however estimate copper and iron with much more accuracy than his processes permit of, by means of Volumetric Analysis. There are only two or three minerals of commercial importance of which the valuation made according to Plattner would avail commercially.† We must not forget however that Plattner's cabinet is mainly a metallurgical one, and that the estimations stand comparison better with metallurgical than with chemical assays: nearly all the determinations are done by the blowpipe, and wet methods are only introduced in a few instances. Ores of iron and zinc, of lead and manganese, cannot be valued by means of the blowpipe.

I have not yet been able to find any account of a portable chemical cabinet of appliances specially designed for, and shown to be able to perform the valuation of those common metals which are technically of the first importance. Nor am I aware that such a cabinet can be obtained in this country, or indeed abroad. My friend Mr. Collins tells me that he has felt the want of a cabinet which is neither a toy collection nor a set of lecture table apparatus. A few months since, being in expectation of making a visit to Servia, I worked at the processes about to be given with an idea of constructing a cabinet useful for the purposes of mining research.

Under what circumstances does the analytical chemist travelling abroad upon a mineral survey, pursue his vocation? He is usually away from the

* The previous work of Berzelius (1820) and of Harkort (1827) contributed, however, to Plattner's success.

† I do not wish in any way to undervalue the excellent work that is done all over the world by means of the blowpipe. A pocket case is of great service in the field, and enables the mineralogist to discriminate between valuable and non-valuable minerals in a number of instances: that is to say, between those which are worth and those which are not worth more accurate chemical investigation. While acknowledging the importance of Blowpipe Chemistry, I cannot acknowledge that it fulfils the requirements of technology in an adequate manner. Plattner's complete cabinet of Blowpipe apparatus sold in this country at 30 guineas, does not suffice for the scientific valuation of ores of the common metals.

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vicinity of towns,—never, however far from some small village. Here he sojourns while making incursions into the surrounding country. After collecting his specimens he returns to the village and takes the first opportunity of making some determinations. Distilled water is not to be obtained unless the village apothecary has a still, and can be induced to use it; our chemist cannot burden himself by taking a sufficient supply. Kettles among non-tea-drinking people in the south of Europe are very rare; and should he succeed in obtaining one and concocting a condenser, his work would still be considerably delayed. Therefore he must be content to use the common water of the place, which if it gave a considerable precipitate with ammonia oxalate it might be advisable to boil and filter. By the system I adopt, however, common water may be used without purification. Provided that the water is fairly free from iron and suspended matter, a condition generally fulfilled, it may be used in the estimation of the constituents enumerated in the subjoined scheme of analysis. I have found a difficulty with the sulphur estimation: until that is satisfactorily overcome our chemist must wait for the wet season.

Another difficulty in out of the way places is to provide the source from which heat is derived. Gas is of course out of the question. In Italy and Spain there may sometimes be found among the culinary arrangements of the household, small round charcoal furnaces built in brick which are useful to heat an iron plate. But as a rule no casual sources of heat such as this should be relied upon. Oil can easily be obtained in the south of Europe, and need not form an item of the collection. It is burnt in an Argand lamp placed underneath an iron plate six inches in diameter. This serves to heat flasks and beakers, to boil water, and to evaporate liquids contained in small Berlin dishes, which are supported on the plate by tinned iron rings. A spirit lamp is used to ignite crucibles, &c. A flask of spirit is carried in the case, and the flask can be replenished in towns. Another Argand lamp heats a small air bath, the top-plate of which can be used for precipitation and slow evaporations. A Plattner's Blowpipe lamp is fed with equal volumes of oil and alcohol. Pisani recommends a mixture of six volumes of spirits of wine and one of oil of turpentine, to which is added several drops of ether. He found that this liquid gave a bright flame, and evolved no unpleasant odour, its heating power when urged by the blowpipe was sufficient to fuse the end of a platinum wire 0·2 mm. in diameter, and to melt an iron wire of 0·3 mm. in diameter into a globule of a millimetre in radius. He was also able to melt 23 grams of silver, and to cupel 5 grams. of argentiferous lead by its means.

We now come to consider the nature of the processes employed. The principle upon which they are worked out lies in the employment of $\frac{1}{10}$th

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of the quantity of substance usually operated upon, and both re-agents and appliances are similarly arranged in miniature. The centner of 100 mg. was first I believe used by Plattner, and this is the quantity of mineral which is used in the estimations. Gravimetric determinations are avoided where practicable, and volumetric processes supply their place. The greatest objection to such a course of procedure is that the eye is not as delicate in discriminating end reactions as the operator might wish. My own power of discriminating tints is rather below than above the average. I think I may state however, that determinations of the common metals may be made without the error exceeding 1 p.c. of the substance operated upon. I think I may go further;—if 100 milligrams of mineral be taken—such minerals for example as calamine, hematite, copper pyrites, carbonate of lead, chromic iron,—the variation from the truth which careful determinations will exhibit will not exceed 0·5 mg. and will be frequently considerably closer.

The estimations which are of most importance in the valuation of minerals for commercial purposes may be given as follows:—

1. Iron ores—iron, phosphoric acid, silicious residue.
2. Manganiferous iron ores—manganese in addition to the above.
3. Chrome iron ores—chromium.
4. Manganese ores—manganese peroxide and manganese.
5. Copper ores—copper.
6. Lead ores—lead and silver.
7. Zinc ores—zinc.
8. Cassiterite—tin, iron, silicious matter.
9. Cobalt ore—cobalt protoxide.
10. Antimony ore—antimony.
11. Mineral phosphates—phosphate of lime ($Ca_3 P_2 O_8$).

(1.) IRON ORES.

The iron is measured volumetrically by bichromate of potassium. The standard solution is made so that 1 c.c. shall equal 4 mg. of iron. As the bichromate can be obtained nearly pure in the shops, by taking the theoretical quantity, the right standard is very nearly obtained. Theoretically 1·758 grams. should be dissolved in half a litre of water; the solution then oxidizing 4·000 mg. of iron per c.c. As a mean of two results 1.750 gram. was required in practice; another sample of bichromate gave 1·754 gram. The purity of the salt however must not be relied upon, and in this case as in every other the true value of the standard liquid must be found by direct titration.

The spotting is done with a very dilute solution of potassium ferricyanide, a drop of which should give but a faint tinge of yellow when

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placed on the porcelain plate. The acid solution of iron chloride after complete reduction by zinc, is carefully and rapidly turned into a small Berlin dish, and titrated. It should not measure more than 20—30 c.c. including the washings of the flask. When the end reaction appears on the plate a little ferricyanide is run into the dish by means of a fine piece of glass tube, the same in fact with which the spotting on the plate is done. A green coloration denotes that a drop or two more bichromate is required; a whitish or yellowish coloration shows when the reaction point is reached.

With the burettes used one drop is sufficient to produce the final change in a definite and recognizable manner. The drops let fall by the burettes weigh about 27 mg. and correspond to 1·1 decimilligram of iron or 0·11 p.c. upon a centner of 100 mg. of iron ore. The burette used is an ordinary 20 c.c. Mohr. and its readings are correct to within 0·02 cubic centimetre.

Each cubic centimetre is divided into 10 parts, and each part is again divided into 10 by the eye, this can be done after a little practice with ease and accuracy. One hundredth of a cubic centimetre is thus read off, and as there are 37 drops of 27 mg. each in 1c.c.,a fraction of a drop may be measured. This is, however, usually unnecessary. Under these circumstances the following results were obtained with fine-drawn soft iron wire; the wire contains 99·8% of iron, a constant by which the weight of iron taken is multiplied.

1 c.c. Bichromate = 4·000 mg. iron.

	Iron wire taken.	*Equal to Pure Iron.*	*c.c. of* $K_2 Cr_2 O_7$.	*Iron found.*
A	70·0 mg.	69·9 mg.	17·54 c.c.	70·16 mg.
B	79·0 ,,	78·8 ,,	19·71 ,,	78·84 ,,
C	61·8 ,,	61·7 ,,	15·40 ,,	61·60 ,,
*D	49·64 ,,	49·64 ,,	12·41 ,,	49·64 ,,

A sample of micaceous iron ore was next operated upon. My friend Mr. W. E. Dawson determined the iron in this ore in the ordinary manner, and found it to amount to 62·33 p.c. I may state that as a rule my results are slightly higher than his owing, to a slight difference made in judging the final reaction. Five centners (or 500 mg.) of the dried ore were dissolved in hydrochloric acid, the liquid was diluted and filtered into a 50 c.c. measuring flask.

A. 10 c.c. (=100 mg. taken) took 15·64 c.c. $K_2 Cr_2 O_7$ = 62·56 p.c.
B. 10 ,, ,, ,, 15·65 ,, ,, = 62·60 p.c.

*5 c.c. of a standard sol. of $FeSO_4$ were taken, 50 c.c. of which solution was known to contain 0·4964 gm. iron as $FeSO_4$.

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The solution of ferric chloride is reduced with pure re-distilled zinc. This can be obtained in Germany at about 6 marks a kilo. The reduction is conducted in a small flask on an iron plate, the flask being covered with a watch glass; or a test tube may be used.

Phosphoric Acid.—This estimation can be effected with accuracy by weighing the phospho-molybdate precipitate obtained from 5 centners of ore. The errors when the operation is conducted in accordance with the principles observed by persons of experience does not exceed 0·01 p.c. The precipitation is conducted at a temperature of from 50°—60°C; the whole bulk of liquid not exceeding 30c. c. Five centners of ore containing 0·05 p.c. of phosphoric acid gives a precipitate weighing 7·5 mg. which can be weighed to a fraction. Boussingault's constant of 0·0373 is used to deduce the phosphoric acid; 0·01 p.c $P_2 O_5$ should be added for loss and solubility. The yellow precipitate, it should be mentioned, is washed off the filter into a small platinum dish in which it is dried on the iron plate and afterwards weighed.

Silicious Residue.—This determination is made gravimetrically in the ordinary manner upon 500 to 1000 mg. of ore, the filtrate from which is used for the other estimations. The results agree to within 0·2—0·3 p.c. The silica in the residue can be determined by fusion. The silicious residue should be determined *after evaporation to dryness*, and so stated.

If it is important to notice if an ore is calcareous or silicious in nature, a rough indication may be obtained by observing if the addition of an acid produces a strong evolution of carbonic acid.

(2.) MANGANESE PEROXIDE.

This is estimated in Pyrolusite, &c., by boiling about 200 mg. of the ore weighed in a small glass tube in acidulated ferrous sulphate solution; 1000 mg. of cryst. ferrous sulphate is dissolved in a hot boiled 10 p.c. sulphuric acid solution in a flask, the tube containing the manganese is carefully dropt in after decomposition, the liquid is titrated with bichromate. Ferrous sulphate is taken to contain $\frac{1}{7}$ of its weight of iron; I find it to be more exact than taking the theoretical figure. A blank assay was made without putting the manganese into the flask, the liquid being boiled for a $\frac{1}{4}$ hour by itself. It yielded the following results: iron taken 44·44 mg., iron found 44·44 mg.

Manganese.

Metallic manganese is estimated with accuracy by Pattinson's method (Q. J. Chem. Soc. June 1879, p. 365), upon 100 mg. of ore. Every particular has to be conducted upon the miniature scale adopted in this system of analysis. The ore is dissolved in a flask with a few cubic

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centimetres of hydrochloric acid, and about 100 mg. of anhydrous ferric chloride is added after the excess of acid has evaporated, and 10 or 15 c.c. of water has been added. The liquid is now neutralized with chalk, until a slight precipitate falls, ten c.c. of a clear solution of bleaching powder are now added and 50—60 c.c. of boiling water; the liquid is immediately neutralised with 250 mg. of chalk and well stirred; it should be placed on the hot iron plate for a few minutes but not boiled. The flocculent precipitate is brought upon a filter and washed until the washings are shown to be free from chlorine by a drop of potassium iodide and starch. The filtrate must be pink; 0·10 p.c. of manganese is added for the manganese converted into permanganate, which is lost. While this is going on, 600 mg. of ferrous sulphate crystals are accurately weighed, and dissolved in 50 c.c. of hot 10 p.c. (vol.) solution of sulphuric acid. The filter with its contents is placed in a small dish, the ferrous sulphate is poured upon it, and, after stirring, the liquid is titrated with bichromate The constant from Fe found to Mn wanted is 0·491. In manganiferous iron ores ferric chloride is not wanted. A manganese ore gave

Manganese present 47·39 p.c. Manganese found 46·73 p.c.

(3.) Copper.

De Haen's method is used, but the iodine solution is dispensed with. The copper is separated from the ore as sulphide by boiling the sulphuric acid solution with sodic hyposulphite. The sulphide is roasted in a porcelain crucible, and treated with hydrochloric and a few drops of nitric acid. After evaporation it is treated with sodic acetate and one gram. of potassium iodide, and the copper estimated with hyposulphite and starch. The hyposulphite solution is made so that 1 c.c. = 1·0 mg. of copper, but this standard will decrease,* and must be tested every few weeks with pure copper.

A standard solution was made from a stronger solution, the titre of which was known. A standard solution of pure copper was made, 5 c.c. of which contained 25·25 mg. of copper:

1 c.c. hyp. = 1·000 mg. copper.

Copper taken.	*c.c. taken.*	*Copper found.*
25·25 mg.	25·1 c.c.	25·1 mg.
25·25 ,,	25·3 ,,	25·3 ,,
25·25 ,,	25·25 ,,	25·25 ,,
25·25 ,,	25·5 ,,	25·5 ,,
25·25 ,,	25·5 ,,	25·5 ,,
Mean 25·25	25·33 c.c.	25·33 mg.

* Ammonium carbonate (1 grm.) is added to preserve this solution.

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I think I may therefore assert that the copper estimation can be made within 0·5 p.c. of the truth. For the whole of the copper present in the ore is completely separated by hyposulphite of sodium sulphuric acid solution, and the substances which may possibly contaminate the precipitate do not interfere with the reactions. If the analysis of very rich ores is contemplated, the hyposulphite solution should be twice as strong.

(4.) SILVER.

Silver is estimated metallurgically according to the directions of Plattner, the blowpipe apparatus commonly used is therefore included in the cabinet.

(5.) LEAD.

There is a volumetric method for the estimation of lead by precipitation as chromate, and the subsequent titration of the chromic acid set free by sulphuric acid from the isolated salt. This method can be applied to all lead minerals, is rapid, and yields fairly accurate results. Carbonates of lead are dissolved in nitric acid, sodic acetate is added and then potassium bichromate; the lead chromate deposits at a gentle heat and can be filtered and washed with rapidity with galena; where the nitric acid produces sulphate of lead, the bases in the solution are converted into sulphates, and the sulphate of lead, &c., is filtered as usual. This latter is converted into carbonate of lead by digestion with carbonate of soda, the precipitate is filtered off, dissolved in acetic acid, and treated with potassium chromate.

In operating with small quantities I have found that sulphuric acid does not set free the whole of the chromic acid. Small quantities of undecomposed chromate may be seen by the eye. The following experiments establish this fact; 50·0 mg. of pure lead was precipitated from its acetic acid solution as chromate. The chromate of lead after filtration was placed in a dish together with its filter, and an excess of ferrous sulphate together with dilute sulphuric acid was added to it. The whole was boiled for some minutes, but traces of chromate of lead were still visible. It was then titrated by bichromate (4·000 mg.) of which it took 2·52 c.c. (=10·08 mg. Fe). The ferrous sulphate taken corresponded to 49·6 mg. iron. Therefore 49·6 − 10·08 = 39·52 mg. iron, which, multiplied by the constant for deducing lead from iron: gives— 39·52 × 1·232 = 48·7 mg. of lead found, instead of 50·0 mg. taken. Another experiment gave 47·2 mg. instead of 50·0 mg. In order to obviate these important errors, another course was finally adopted. The amount of chromic acid in solution after the lead had precipitated was determined. To the acetic acid solution of lead 14·95 c.c. of bichromate

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solution was added; the liquid was warmed and filtered. To this filtrate 49·6 mg. of iron, in the form of ferrous salt was added. The excess of ferrous salt took 7·53 c.c. of bichromate.

$14{\cdot}95 \times 7{\cdot}53$ c c. $= 22{\cdot}48$ c.c. $K_2 Cr_2 O_7 \times 4{\cdot}000 = 89{\cdot}92$ mg. iron
Iron in ferrous salt used $= 49{\cdot}60$,, ,,

Chromic acid withdrawn by lead $= 40{\cdot}32$,, ,,

To deduce lead: $40{\cdot}32 \times 1{\cdot}232 = 49{\cdot}67$ mg. lead found, instead of 50·0 mg. of lead taken.

Four burette readings of bichromate were taken in this experiment, and the error of the estimation was 0·33 mg. lead. This corresponds to 0·07 c.c. of the burette. The error of a reading need not amount to more than 0·02 c.c., and therefore since these errors would not extend always in the same direction, the burette measurements need not introduce any serious source of error.

(6.) ZINC.

If sulphide of zinc could be washed without loss, this metal might be advantageously determined by ferric chloride and bichromate. But the foregoing is a difficulty which renders the process useless to the practical assayer. The best results I obtained exhibited considerable deviation from the amounts of zinc taken, owing to this source of error, for example:—

Zinc taken.	*Bichromate taken.*	*Zinc found.*
20·0 mg.	9·03 c.c.	21·0 mg.

Schaffner's process was found to be impracticable with small quantities of substance; the same may be said of the ferricyanide and iodine method. Fairly good results were obtained with potassium ferrocyanide in hydrochloric acid solution, using uranium as indicator; and I consider this method to be reliable, and more applicable to the estimation of small quantities of zinc than any other with which I am acquainted.

Potassium ferrocyanide like potassium bichromate can be obtained in England tolerably pure; a weighed quantity will therefore give a standard approaching the true one. The theoretical equivalent however must not be taken, because the composition of the precipitate formed is not established. To make a solution 1 cubic centimetre of which shall equal 2·00 mg. of zinc, 4·4 grams. of ferrocyanide should be dissolved in 500 c.c. of water. Two separate samples of the salt were used to make two standard solutions, each equal to 2·00 mg. of zinc per cubic centimetre; in the one case 4·33 grams. ferrocyanide were required, and in the other 4·42 grams.

The operator finds the standard of his solution by means of pure zinc, a stock of which he carries with him. The zinc is separated from the

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iron in the ore, &c., by double precipitation with ammonia. , Manganese in quantity interferes with the accuracy of the results, but is not often present in calamine and blende. Copper if present is separated from the sulphuric acid solution by boiling with a gram. of sodium hyposulphite; after oxidizing any iron present, the liquid is precipitated by carbonate of soda, and evaporated somewhat in a porcelain dish, the precipitate is re-dissolved in a little hydrochloric acid after filtration, and the iron is separated by ammonia as usual. The bulk of the liquid before titration should not exceed 20—30 c.c.

The following results have been obtained:—

I. The standard solution was equal to 1·50 mg. zinc per c.c. known weights of pure zinc were taken.

Zinc taken.	*c.c. taken.*	*Zinc found.*
33·2 mg.	22·0 c.c.	33·0 mg.
34·6 ,,	23·0 ,,	34·5 ,,
34·6 ,,	23·0 ,,	34·5 ,,
34·6 ,,	23·6 ,,	35·4 ,,

The last result was produced in the presence of 5 c.c. concentrated hydrochloric acid, showing that considerable excess of acid must be avoided.

Zinc taken	*c.c. taken*	*Zinc found*
25·0 mg.	16·8 c.c.	25·2 mg.
32·4 ,,	21·9 ,,	32·5 ,,

II. Another standard solution of zinc (1c.c. = 2·58 mg.) was made. The following determination was made in acidulated ammonium chloride solution, to correspond with the actual testing.

Zinc taken	*c.c. taken*	*Zinc found*
40·0 mg.	15·5 c.c.	40·0 mg.

In an acid solution containing no ammonium chloride two determinations gave.

Zinc taken	*c.c. taken*	*Zinc found*
40·0 mg.	15·7 c.c.	40·5 mg.
20·0 mg.	7·8 c.c.	20·1 mg.

The standard of the ferrocyanide should be determined in the presence of 0·5 to 1·0 gram. of ammonium chloride. In these experiments the reactions were distinguishable to within 0·2 c.c. Care *must* be taken that the ferrocyanide is run in a few c.c. at a time, with shaking. The testing must be continued until the addition of 0·2 c.c. from the last reaction produces, upon standing for a moment or so, a permanent deepening in the colour of the spot.

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Zinc can be estimated in the manner described to within 1 p.c. of the true content of the ore. A correction of 0·5 p.c. might perhaps be added in the case of ores containing much iron or copper.

I have made a few estimations by this process in some complex metallic sulphides containing Blende from Sardinia, and obtained the following results.

	Gravimetric determinations.	*Miniature Volumetric. Method.*	*Difference.*
Zinc	24·54°/₀	24·63°/₀	0·09°/₀
Zinc	11·54 ,,	11·86 ,,	0·32 ,,
Zinc	18·01 ,,	18·38 ,,	0·37 ,,

(7) TIN.

Cassiterite is assayed by boiling 1 grm. of the mineral with strong hydrochloric acid to remove iron; in rich ores about 0·1 p.c. of tin oxide is rendered soluble by this operation. The insoluble residue is dried and fused under crude potassium cyanide in a small crucible. About a gram. of ore should be taken, the principal source of error lies in uncertainty as to whether the whole of the tin has collected in the button: of two assays therefore the highest should be taken.

(8) COBALT.

Cobalt is estimated by boiling the mineral containing it with aqua-regia in a small conical flask: after evaporating the excess of acid the liquid is neutralized with sodium carbonate, and a hot concentrated solution of potassic acetate is added to precipitate the iron, arsenic acid, silica, &c. The filtrate is evaporated to 10 or 15 c.c. and 3 c.c. of a saturated solution of potassic nitrite rendered acid by acetic acid, is added. The cobalt nitrite is dried and weighed as usual. Two centners of ore are taken for the estimation.

(9) ANTIMONY.

One centner is boiled with aqua-regia; tartaric acid, ammonia and ammonium sulphide are added, and the liquid is filtered. Acetic acid precipitates arsenic and antimony in the filtrate. These are separated by Bunsen's method, using sodium sulphite acidulated with hydrochloric acid. The antimony is weighed as $Sb_2 O_4$.

(10) PHOSPHATE OF LIME.

This estimation is made by uranium solution of which 1 c.c. = 2·00 mg. phosphoric acid.

To prepare the liquid to be titrated the following procedure is adopted. The sample is powdered, and ground in the agate mortar until soft to the

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touch, *like flour*. Five centners are weighed, placed in a clean dish and mixed with cold 5 p.c. solution (volume) of dilute sulphuric acid, by triturating with a pestle; 20 c.c. of this acid suffices. The last few cubic centimetres are used to wash out the dish after the contents have been poured into a 50 c.c. flask; a little water may also be used. After standing for several hours, with occasional shaking the liquid is made up to the mark and 0·3 c.c. water added. The whole is filtered through a dry filter into a dry flask. Ten cubic centimetres (=100 mg.) are neutralized with carbonate of soda and made just acid with acetic acid; the titration is then proceeded with. Another 10 c.c. should be used to check the result. Some crystals of pure uneffloresced rhombic phosphate of soda are contained in the cabinet and are used to standardize the uranium solution. Of this salt 1·01 gram. is weighed off (after powdering and pressing between filter paper), dissolved in water and made up to 100 c.c. 10 c.c. of this liquid (=20·0 mg. P_2O_5) is placed in a flask, a few drops of carbonate of soda and finally of acetic acid are added (to acid reaction), and the liquid is titrated hot as usual.

A phosphate containing 35·86 p.c. of phosphoric acid was found to contain 35·99 p.c. P_2O_5 when working with a uranium solution 1 c.c. of which equalled 1·290 mg. P_2O_5.

Having described the analytical methods adopted, we now come to consider the arrangements by means of which they are carried out.

For this purpose it will be convenient to consider these arrangements under four heads, namely;—

1. The measuring apparatus and standard solutions.
2. General apparatus for analytical work.
3. Chemicals, liquid and solid.
4. Cabinet arrangement.

1. *The measuring apparatus, &c.*

The balance is constructed with the special object of portability. It takes a maximum weight of 10 grams. and indicates accurately 0·0001 grams.—(one deci-milligram). A folding glass case is erected over it when in use and packs into the same box, occupying a space of about 8×8×3 inches.

The burettes, two in number, are of Mohr's construction. They measure 20 c.c. of liquid, with a delicacy of measurement of within

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$\frac{1}{50}$ c.c. They are supported by a brass upright 10 inches long which screws into the centre of a rectangular base. This base, or foot is half covered with a porcelain plate which is screwed into it. This serves for spot reactions. These burettes, their stand and appurtenances, are fitted exactly in a box 8 inches wide 15 inches long and 2 inches in external thickness. This box contains moreover six pipettes, one 10 c.c., one 5 c.c., two 2 c.c., and two 1 c.c. in capacity; the whole arrangement is independent, so to speak, of the rest of the cabinet.

Four standard solutions are carried in the case. Each bottle contains 500 c.c. of liquid, which seems to me to be the minimum quantity consistent with the objects in view. Potassium Bichromate, Potassium Ferrocyanide, Uranium Acetate, and Sodic Hyposulphite are found to be sufficient for most practical purposes. These bottles have well ground stoppers which are tied down by caoutchouc caps. Two more 500 c.c. bottles containing ammonia and hydrochloric acid are fastened down in like manner. The six bottles are contained in a drawer $10\frac{1}{2} \times 15 \times 8$ inches, in which the burette box likewise finds a place.

Four measuring flasks are provided, of respectively, 250, 200, 100 and 50 c.c. capacity. They are contained in a drawer of the same case.

2. *Apparatus.*

1. Plattner's blowpipe apparatus for cupellation; in separate case.
2. Platinum crucible and dish; platinum wire, and swing for crucibles; platinum forceps.
3. Six porcelain crucibles; six porcelain dishes for evaporation, (smallest size). One three inch porcelain dish for iron tests. Tinned ring supports.
4. Copper drying bath (hot air) with holes in top for basins, crucibles, &c.
5. Round iron plate (6-in). Iron wire gauze 1 sq. ft.
6. Heating apparatus. Two small argand burners for oil; a ring support slides on the brass upright. One spirit lamp: a tin can containing $\frac{1}{2}$ litre of spirit.
7. Beakers, 2 sets of three (small size). Flasks of 60-70 c.c. capacity, eight.
8. Funnels, assorted, six: close and open filter paper 12 packets.
9. Miscellaneous: test tubes, watch glasses, stirring rods &c.
10. Two washing bottles of 250 c.c. capacity, for hot and cold water.

3. *Chemicals (liquid and solid.)*

1. Six 250 c.c. glass bottles containing nitric, sulphuric, and acetic acids; ammonium sulphide, ammonia nitro-molybdate, and carbonate of soda, (solutions.)

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2. Sixteen two ounce re-agent bottles containing ferrous sulphate, carbonate of soda, carbonate of lime, anhydrous ferric chloride, sodic phosphate, potassium dichromate, potassium ferrocyanide, potassium chlorate, sodic sulphite, potassic cyanide, bleaching powder, barium chloride, potassium nitrite, sodic acetate, potassium iodide and potassium ferricyanide.

3. In small turned wood boxes: starch, pure lead, electro-type copper, and litmus paper.

4. A bag of redistilled zinc, free from iron.

4. *Cabinet Arrangement.*

The aforesaid re-agents and appliances are contained in two cases of hard wood for the sake of portability. A strong leather handle is affixed to the top of each case so that it may be carried like an ordinary portmanteau. The cases are of the same size, viz. 13-in. deep, 17-in. high, and 17-in. in diameter (the depth is given at right angles to the height when the case is standing upright). The first case contains simply two drawers with partitions in which the burette box, the standard solutions, the flasks, and miscellaneous glass apparatus find their place.

The second case contains one drawer, the rest being open spaces, in which are stowed the balance, the blowpipe apparatus, the liquid and solid reagents, the heating apparatus and miscellanea. By these arrangements the cases are weighted as evenly as possible. Both cases are bound in green baize or leather and studded with brass nails.

N.B. The chests will be made by Messrs. E. Cetti & Co., of Holborn, the celebrated glass apparatus manufacturers.

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VII.—*Further Notes on Mineral Growth.*

By T. A. Readwin, F.G.S., M.R.I.A., &c.

WHEN I read my first paper on "Recent Mineral-growth at ordinary temperatures" under (what we, perhaps, rather carelessly call) "ordinary conditions,"* I was met with the reasonable remark that, time enough had not elapsed for me to be *certain* of my facts.

Since then, I have had more than three years of affectionate watching in my "Gold-garden" (as Mr. Ruskin pleasantly calls it); and I am glad to say that the interim has been productive of some new and striking spontaneous changes; which, for convenience of expression, I continue to term "mineral-growth."

I have before me a number of mineralogical facts of much interest, and I propose to notice first, some recent alterations in 47 of the specimens described in the paper referred to; and then to add a few short notes of similar changes in 35 specimens, not therein alluded to.

On page 167 of the Mineralogical Magazine, vol. I, I describe some *Iron-growths* out of a specimen of Magnetic Iron-ore; cabinet number Fe 840. With this, I have associated another specimen (Fe 840*a*), a portion of 840. These two bits of minerals are positively amusing as well as suggestive.

It happened on the 13th of May last, I had occasion to show them to the Hon. J. K Howard, at the office of Woods, Forests, &c., and then for the first time I noticed a broad protrusion about ¾ of an inch long, standing straight out, almost level with the bottom of the tray in which it now is.

On examination next morning the protrusion had disappeared. It had, somehow, got underneath the specimen, had flattened and attached itself again to it.

I then discovered that the protrusions (too many to count easily), would attract or repel one another.

I placed the two specimens upon the glass-top of the box, about half-an-inch apart, when, presently the biggest bit drew the other more than half-round in a second of time; the little one snatching sundry protrusions from its big brother in transit. The little thing assumed a rough resemblance to the stuffed black baby-elephant at the

* Mineralogical Magazine, Vol. I.

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British Museum, with partially hairy body and a proboscis-like protrusion, more than half-an-inch long.

I again put the larger piece about the same distance off, and it behaved in exactly the same way as my magnet.

On moving the big bit, the proboscis of the other invariably turned in its direction, prior to its bulk doing the same.

Some of the protrusions occasionally recede telescope-like; others project somewhat in the same fashion.

It is interesting to note that a stone broken in 1873 or 1874 should behave thus. Common enough, perhaps, though not often noticed. I have a memorandum on the labels 19, V. 78. "Numerous flake-like growths formed after the manner of the artificial Lead-tree. Very interesting."

On page 168, No. 100^{e}. (Native Copper.) "The vertical accumulation" is now more than one-eighth of an inch increased by the growth of the crystallized form, at its apex. The "column" is now separated at both sides from the longitudinal exudations. The "loop" is fast tending downwards, and has a tendency to collapse and unite with the column. The exudations all along the line have increased in bulk; and some minute copper-crystallizations have appeared on the stone, at some distance from the others. Most interesting.

848 (Argentite.) White Silver-growths very considerably multiplied.

On page 169, No. 18 (Argentite) has on it very many recent curly silver-growths.

846 (Argentite) has a few recent silver-growths.

16^{e} (Argentite.) Silver has grown very much in curls.

More than 25 grains weight of silver has grown off the last three specimens in about 12 months, and the bottom of the tray is covered with dirty silver-dust.

On page 170. No. 2 (Moss-copper in small glass-topped box.) One filament has very much grown in length; other filaments have changed in colors, and one of the largest has become silvery-white! *Mem.* 5, v. 80. White appearance has disappeared. *Mem.* 1, VI, 80

On page 171. 86 and 92. (Quartz.) Electrum-growths are much changed.

100^{t}. Interesting electrum-change in a cavity.

100^{r}. Electrum enlarged very much.

217. Globule in indexed cavity in process of changing form.

On page 172. 217, 100^{n} (Au., Bi., Te., &c.,) and No. 7 (Electrum) have enlarged considerably.

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13[a]. The larger gold-growth has perceptibly increased, and another has appeared in a cavity. A growth at a corner of the specimen has considerably increased in bulk, and appears in process of crystallizing. Increase noticeable within the last 16 days.

276 and 276[a] (Electrum) more generally crystallized.

On page 173, No. 12 (Sponge-gold) changes remarkable.

On page 174, No. 556 and 532 (Quartz-crystals.) Electrum-growth thereon increased.

On page 175, 583. "Mitre-shaped" electrum-growth increased.

501. The interesting electrum-growth is now five-sixteenths of an inch long; being rather more than one-sixteenth longer than when I measured it at the beginning of this year. It has also increased sensibly in bulk. The longitudinal groove is deeper. Another groove has appeared all along an opposite edge. This remarkable growth appears separating at its base, and I fear will, some day, *grow off*, as other electrum-growths have frequently done. At present, however, it is very firmly fixed in the quartz.

On page 176, No. 832. Large quartz specimen loaned in June, 1878, to the Liverpool Museum, examined by me Dec. 16, 1879. Found that one of the largest electrum-growths, and several smaller ones had grown off. There appeared, also, several recent growths.

No. 834 show electrum-specks recently *grown off*.

On page 177, No 594, at index *a*, Electrum palpably developed in length. At *b*, Electrum, apparently, crystallizing into cubic form.

815. The "antler-like" electrum-growth in the gossan-lined cavity has sensibly increased; and, at the edge of the cavity, the electrum has burst through its gossany-coating, and is beautifully bright.

581 has most interesting bright recent electrum-growths in two cavities of the quartz.

525 has electrum considerably increased.

On page 178, No. 511 (quartz.) Electrum has grown and become very interesting. Is probably changing shape to isometric-shape.

566 (quartz) shows recent electrum-growth.

535. Some threads of Moss-gold have fallen off; and others have perceptibly grown. Electrum in cavities, much grown. Here are, also, some new growths.

587. Electrum has increased in bulk in several places, and here are three new growths.

520. Copper-looking growth of electrum.

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123. Grooves in electrum deeper, and a division likely to take place shortly.

On page 179, No. 196. Electrum increased in length.

No. 10 At index *a*, a gold-crystal forming in cubical system.

At index *b*, electrum has grown off, and in its place have appeared four tiny bright forked branches of electrum.

At index *c* is electrum crystallizing; and also in a cavity behind it are several recent branch electrum-growths.

At *d*, electrum has grown 1-18th of an inch, and has become cork-screw-like in shape.

At *e*. electrum has become much more branched and rather loose. Near it are two recent electrum-growths.

At *f*, electrum crystallizing into cubic form.

Page 180, No. 220 (Brown Blende). Recent electrum-growth at one end of specimen.

215 (Galena, &c.) Electrum-growths, palpably increased. Specimen has become very interesting as to spontaneous movements.

97 and 98. Electrum growths increased in bulk.

502 The scoop-like electrum-growth is now ¼-inch in length; has curved further into the cavity by nearly 1-16th of an inch, has become stouter, and more rugged. The trefoil-like growth in the gossany-cavity has changed its shape by the elongation of its centre-portion.

On page 181, No. 22ª. Electrum-growths increased, and recent ones have appeared in the *undecomposed* marcasite.

207. Electrum-growths palpably increased. The "broad-growth" at the thinnest edge of the specimen in May, 1877, was barely 1-16th of an inch high; it is now more than ⅛th of an inch.

117ª (Mispickel.) The electrum in this specimen has grown fully ⅛th of an inch since I measured it in December last, it thinned out in its process of elongation, and electrum ¼ × 3-16ths inch grew off. Since then, the grown-off portion has curled a little at the edges, and has a tendency to isometric crystallization.

The remainder of the electrum-shape attached to the quartz and unassociated with the auro-pyritous mineral, has sensibly increased in bulk; exhibits a tendency to cubical-crystallization, and is now beautiully bright.

The growth originating in the quartz-cavity has protruded still further, and the cavity appears as if likely to get rid of its tenant at no distant period.

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The Mispickel has not in the least decomposed, and no electrum is at present to be seen at its surface.

On page 182, No. 49. The electrum looks more like Native Copper than it did. It would pass for native copper in an ore-heap.

236. The beautiful gold-crystals on this specimen had upon them what appeared to be "parasitic black crystals." Most of them have pushed off their *black coating* and revealed bright faces of octahedra crystals.

The black crystals are now much less numerous. Some are to be seen apart from the principal cluster of gold-crystals. These I have not before noticed; but cannot say positively that they are recent.

The twin-crystals, of which there are, perhaps 200, are very interesting.

20. Some electrum crystallizing into isometric form.

818. The twin electrum-crystal, decidedly increased in bulk, and has become beautifully bright. The other growths have also progressed.

On page 183, 841. Apex of the crystal much brighter.

At index *a*, the electrum-growth in the quartz has increased, and become more pointed. About half-an-inch off it, another growth has appeared. Gold has come to sight in some adjacent blende.

500[r]. Red index *a* points to gold-pseudomorphs in a cavity. Two of these have become brighter at their extremities. In another cavity are some recent dirty-looking electrum-growths; and in a cavity adjacent to this, are some recent bright growths.

On page 229 of the same volume I described some Norwegian (Kongsberg) minerals.

13 Ag. exhibits several recent argentite-growths.

On page 230. 10 Ag. Some new argentite-growths have appeared in a cavity.

11 Ag. shows further development of silver in curly growths.

14 Ag. has elongated a tarnished silver-thread.

On page 231. 6 Ag. shows a bright recent silver-growth out of a slender silver-thread. The growth is out of pistacite.

2 Ag. shows several recent silver-growths.

On page 232. 123 Ag. shows recent silver-growths.

18 Ag. The silver-growth has split open its enclosing calcite, leased itself, and both silver and argentite have curled in places!

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Some recent Mineral and Metal-growths not before reported of.

Specimen 100[d] shows recent Millerite-growth, with electrum-growth out of Mispickel.

699 shows recent electrum-growths at indices *a*, *b*, *c*, *e*, and *f*.

822. Electrum very much increased and recent gold-threads *beautifully bright.*

52. Fifteen electrum-growths sensibly increased, and the specimen during this progress in a most novel and interesting state.

26 y. Lower Silurian schist containing copper pyrites and black blende, shows numerous electrum-growths and crystallization since 12, vii, '77.

771 shows recent electrum-crystallization.

93[a] and 819. Electrum-growths increased.

517. Some interesting electrum-growths.

No. 752. A remarkable change has taken place in the electrum-growths: some of them have become laminated.

58[a] and 564. Electrum-growths much increased, and have become very bright and beautiful.

401. Electrum-leaf grown off and surface crystallizing into form.

99. Electrum crystallizing isometrically.

837. Electrum shape much changed. Shape indescribable.

679, 115, 41, 153, 21, 117, 93, 566. All exhibit recent electrum-growths.

757, 822, and 101. Electrum-growths increased.

82. Electrum-growths much brighter.

99. Electrum grown off *in gold-dust*!

32[b]. Several bright recent electrum-growths in cavities.

115. Electrum-crystallization in cavities.

205[a]. Electrum cubic-crystallization more perfect.

500[a]. Pyrites decomposing after being boiled in Nitric-acid, disclosing long flaky-electrum, some portions of which exhibit recent bright growths. Mem. 6, vii, '80. These growths have all since tarnished.

500[b]. (In round glass-topped box.) These gold-growths much changed in shape since 16th Dec., 1879. Appear to be changing like 501 before referred to. All these have been detached from matrix.

500[c]. Gossany-quartz (like 535 referred to) calcined in 1874, and had then some of the electrum in *globules*. Found by me in a heap,

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June, 1878. Has much changed since. Globules have all changed to undefined shapes.

C. 1. Curved changes in a natural Cape diamond since Dec., 1877.

25. Coil of metallic Cadmium has elongated nearly 1-16th of an inch since January 1st last.

Mem. 6, vii, '80. I have been reading lately Lord Bacon's *Sylva Sylvarum*, published by Dr. Wm. Rawley (1658), and I am tempted to add an extract therefrom in favor of the somewhat objectionable term *growth*.

"EXPERIMENT SOLITARY TOUCHING THE GROWTH OR MULTIPLYING OF METALS."

"It is reported by some of the ancients, that, in Cyprus, there is a kind of iron that, being cut into little pieces and put into the ground, and well watered will increase into greater pieces. This is certain, and known of old, that *Lead* will multiply and increase as has been seen in old statuas (*sic.*) of stone, which have been put into cellars; the fact of them having been bound with *leaden-bands*; where (after a time) there appeared, that the *lead* did swell; inasmuch as it hanged upon the *stone* like *warts*." (p. 168.)

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VIII.—*On some Cornish Tin-Stones and Tin-Capels.*

By J. H. Collins, F.G.S.

Second Paper.

Wood Tin.

In my former paper (*Min. Mag.*, vol. IV, page 1) the different modes of occurrence of oxide of tin in Cornwall were briefly described, and the characters both macroscopic and microscopic of the ordinary tin-stones and tin-capels were illustrated in considerable detail. I have now to describe the peculiar varieties of "wood-tin" or Cornish tin-ore, which are certainly characteristic of many of the Cornish deposits, although their occurrence is not limited to Cornwall as was at one time supposed.*

The chemical composition of Cornish wood-tin differs very little from that of ordinary Cassiterite, as was shewn long ago by Klaproth. The following analyses were given in my Mineralogy of Cornwall and Devon, pt. 2, p. 24 :—

	a.	*b.*	*c.*	*d.*
Oxide of Tin	93·93	96·26	91·0	94·5
Peroxides of Iron and Manganese	0·32	3·40	9·0	1·5
Silica	0·75	0·75	—	1·0
Alumina	—	—	—	3·0
	100·00	100·41	100·0	100·0

a was a specimen from Altarnun, analysed by Klaproth, *b* was analysed by Thomson, *c* by Vauquelin (sp. gr. 6.45), and *d* by Johns.

The following percentages of metallic tin were obtained by means of a charcoal crucible and blast furnace, by Klaproth :—

Light-brown acicular crystals ..	75 per cent.
Grey crystals from St. Agnes ..	74 ,,
Wood Tin	73 ,,
Stream Tin from Ladock	76 ,,
Stream Tin, Altarnun	76 ,,

* Among foreign localities for wood-tin the detrital deposits of the Mexican uplands may be especially referred to. In these many nodular and concretionary masses of a yellowish or reddish-brown wood-tin occur—sometimes associated with the rare mineral Durangite. These, however, unlike most of the Cornish wood-tins, generally contain a very large proportion of oxide of iron.

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The tin so obtained, however, would contain traces of the iron, manganese, and other metals contained in the ore. On the other hand there would be a certain loss of metal in the slag which would more than compensate for the increase from this source in such pure selected ores, so that the results obtained were on the whole remarkably near the theoretically possible quantity of 78·67 p.c. of metallic tin.

The following are analyses made by myself:—

	a.	*b.*	*c.*
Tin	77·80	72·50	74·6
Iron	·21	5·22	2·3
Manganese	traces	traces	1·2
Silica	traces	·31	·2
Oxygen (calculated) ..	21·20	21·86	21·7
Loss	·79	·11	—
	100·00	100·00	100·0

The general appearance of wood-tin has been already described*—the more important varieties are illustrated in the plates VII to XI, which accompany this paper.

The Garth Mine has already been referred to as a notable locality for wood-tin. Balleswidden Mine in St. Just has also been given as a locality.†

The following extracts from Mr. Carne's account of the Garth mine (*Trans. Roy. Geol. Soc. Cornwall*, IV, p. 99) will be found of considerable interest. The paper was read in October, 1830. "The Garth Mine, known also as East Wheal Cock, is situated on the side of a granite hill, about two miles from Penzance, on the Land's-end road. Eastward the lode is in granite, westward in killas, but the workings have all been in the granite portion." After adverting to the former history of the mine, Mr. Carne continues—"About three years ago the Garth was again set at work, with an engine worked by a water-wheel for draining the water: the present workmen, on exploring the lode immediately below the *old workings*, found it productive of tin, and it has continued so to the present depth of thirty fathoms, although scarcely rich enough to pay the expenses which attend the concern: the tin-ground in the lode is about six fathoms in length, and occurs directly westward of the intersection of the lode by a clay cross-course on which the adit was driven; the lode has not been explored east of the cross-course.....In all this space, wood-tin and

* *Min. Mag.*, vol. IV, p. 6.

Some beautiful coloured figures of wood-tin are given in plate 1, of the Catalogue of the Rashleigh collection, published in 1797. A good drawing of the "needle-tin" from Glasteining mine in St. Mewan (now I believe known as St. Austell Consols) is given in pl. 4. Some of these "needles" are extremely fine, but unlike the "fibres" of wood-tin which are nearly opaque, these are very transparent.

† *Rep. Roy. Inst. Corn.*, 1841, *p.* 38

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toads'-eye tin have been plentifully found; tin in globular distinct concretions, from the size of a pin's head to that of a pea has occurred more sparingly; and of botryoidal-tin only a few specimens have been met with....Of the specimens which I have the pleasure to present to the Society,* Nos. 1-6, are of the lode itself: it has in general a very granitic appearance, but it is not granite, its constituent parts (except the metallic ores) appear to be quartz, felspar, and chlorite, coarsely mingled together; the two former highly crystalline. The only metallic ores which I have observed in it are the carbonate of iron and the oxide of tin; the tin is not generally scattered throughout the stone, but exists in singular forms, and in such modes as have been seldom if ever observed before. Where the felspar predominates the tin occurs in small separate layers between the crystalline masses of felspar, possessing the fibrous texture and brown colour peculiar to the wood-tin as in specimens 7-8. It occurs also in contemporaneous veins in the quartz as in No. 9, and in similar veins between the quartz and another constitutent part of the stone as in No. 10,and investing the sides and summits of the quartz crystals as in Nos.11, 12. No. 13 is a specimen of the globular distinct concretions ; on breaking a stone these concretions are often found bedded in one part and capped by the other as in No. 14, when broken they commonly present the appearance of toad's-eye tin as in Nos. 15-16. In some of the specimens two or more of these varieties may be observed in the same stone, as in Nos. 17-18. No. 19 presents the wood-tin with a rough botryoidal surface." Several of the varieties referred to by Mr. Carne are described and figured in Plates VII and IX. The figures are however drawn from specimens in the Truro Museum.

Wood-tin, Garth Mine (Plate VII, fig. 1.) This specimen is in the Truro Museum. It consists essentially of a layer of dark brown wood-tin thinly coating the sides and summits of the large quartz crystals at *c*. This is succeeded by a series of bands of hair-brown wood-tin, grayish quartz, and pale pink felspar several times repeated. At *e* is a band of green chloritic substance which probably formed the wall of the lode from which the specimen was derived. What was the entire breadth of the lode in this part we have no means of knowing as the other side of the specimen is broken away.

Wood-tin Garth Mine. (Plate VII, fig. 2.) This very peculiar figure is also drawn from a specimen in the Truro Museum. It consists mainly of crystals of pink felspar which are just in contact with each other—so as to leave numerous angular interspaces. These are all

* The Royal Geological Society of Cornwall. The specimens are preserved in the Museum at Penzance in wall-case No. 11.

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filled with very compact dark-brown wood-tin, as indicated in the figure. There is scarcely any quartz in this stone.

Wood-tin, Garth Mine. (Plate IX.) This is another figure drawn from a specimen in the Truro Museum. It consists of fine alternating layers of quartz, pink-felspar, and wood-tin, part of a thick band from a granite "country." This is an exceedingly beautiful specimen, but not so rich in tin as the last described.

Wood-tin, Tregoss Moor. (Plate VIII.) This magnificent specimen was found in the slightly water-worn detrital deposits of Tregoss Moor, and is now in the Truro Museum. It has evidently at one time formed part of the filling of a fissure, but the original locality is not known. At *b* the stone consists of a peculiar pale brownish-gray quartz, a *melange* apparently of small irregularly formed crystals. At *c.c.* is a band of moderately large prisms and pyramids of quartz, pointing no doubt as is usual towards the interior of the fissure. Upon and between these crystals is a series of layers of wood-tin, varying in tint from a very pale hair-brown to a very dark chocolate tint, many of the layers being less than one-hundreth of an inch in thickness. Then upon this we have the main mass of confusedly crystalline quartz enclosing smaller patches of wood-tin, and, at the farthest edge a semicircular mass which is no doubt part of a band corresponding to that first mentioned. All the wood-tin here is most perfectly concentric, and also radiated in structure.

How wide the original fissure was cannot be determined, as not the slightest appearance of a wall or selvage is to be seen; but it must have been considerable in the part from which this specimen was derived, even though there had been only these two layers facing each other, i.e. that there was no re-opening and re-filling of the fissure. Its total breadth could not have been less than 6 inches, and may have been as much as 9 or 10 inches. Such a lode would be capable of yielding in each fathom of length and depth nearly two tons of tin-ore. Of course there may have been several such layers in the same fissure, forming a gigantic specimen of "banded" or "combed" structure.

Shot-tin (Pl. X., figs. 1 and 2). This very remarkable form of wood-tin was first noticed by Klaproth—and it is the rarest of all the forms. Its general appearance is very remarkable, that of a number of small brown shot, varying in size from a pin's head to the 16th of an inch, embedded in and cemented together with a greyish-brown cement. In fig 1 a section is drawn as seen with the $\frac{1}{2}$-in. objective ($\times\frac{66}{1}$). The greyish circles are sections of spheres, generally more or less broken or incomplete—sometimes hollow, sometimes containing a kernel of nearly opaque wood-tin. The spheres themselves do not appear to be composed of

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cassiterite, but I am not at present able to say of what material they consist, as I have but a very small fragment of the stone at my disposal. They are surrounded on all sides by distinctly radiated wood-tin, as shewn in the sketch. The matrix encloses a number of prisms which appear to be quartz; similar crystals are embedded in some of the spheres. In fig 2 the same section is shewn as seen with the 2-in. power ($\times\frac{16}{1}$). The specimen from which the sketches are drawn is said to be "from near Penzance," but the exact locality is not known. It is, however, probably from the Garth Mine.

Carvear, St. Austell.—In this specimen the wood-tin occurs in little botryoidal layers and groups of spherules enclosed in nearly white quartz. As in every other case, the spherules exhibit the radiated and concentric structure.

Wood-tin, Prideaux Wood Mine (Plate XI, fig. 1.) This is an illustration of the very remarkable brecciated stanniferous deposit already referred to.* Referring to one of the finest masses discovered, my friend Capt. John Simmonds, of Liskeard, writes me as follows:—"The wood-tin found at Prideaux Wood was discovered in a lode of copper-ore; it was a large kidney-shaped specimen, but, unfortunately the men broke it up to see what it contained, supposing it to be iron. No one knew what it was until I brought it up from underground, and had it bruised down and calcined, when it shewed a splendid "vau" of tin. I have a part of the stone (also some small fragments) which in appearance closely resembles a specimen of wood-iron alongside of it." Some fragments of the included radiated masses (for which I am indebted to my friend Dr. C. Le Neve Foster) are drawn as seen under the microscope in Plate XII.† The appearance to the unaided eye is beautifully represented in the Rashleigh catalogue already referred to. The concentric bands are alternately light and dark-brown, some few being very nearly black.

Wood Tin, Roche—Specimens of wood-tin associated with tourmaline-schist and quartz were presented to the Truro Museum many years since by Mr. W. Mansell Tweedy. One of the specimens, besides the usual narrow bands and botryoidal or mammillary crusts, has a fine circular radiated mass of wood-tin about one inch in diameter. Mr. Tweedy remarks of the wood-tin from this locality, "The specimens were of unusual beauty, one which I obtained for Mr. Williams had the radii at least an inch in length. The specimen I have the pleasure to exhibit will illustrate the character of the larger specimens: it is of a light hair-brown colour internally, darker externally, sprinkled with minute crystals of white quartz, in nodular concretions in a dark, nearly black and

* First Paper, p. 7.

† On analysis this wood-tin yielded 25 p.c. only of peroxide of iron.

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schorlaceous rock. In other specimens the wood-tin in radiating fibrous masses with darker concentric bands, is intermixed with the schorl rock." Some of the specimens exhibit a brecciated structure; the tin mixed with schorl apparently serving partly as a cement. Some of the wood-tin masses are coated with minute nearly black crystals of cassiterite.*

Wood-tin, Gavrigan Mine—A specimen in the Truro Museum marked as above, consists of dark-brown irregular masses of wood-tin, coated with brilliant black crystals of cassiterite, resting upon and occupying fissures in tourmaline schist. It does not essentially differ from the specimens above described as from Roche, and may probably be from the same locality.

Wood-tin, St. Agnes—A specimen exhibited at the annual meeting of the Royal Institution of Cornwall in 1841, was thus described by Mr. W. M. Tweedy, "The specimen from St. Agnes is a fragment showing a portion of the lode and both walls, with some of the *country* on each side, which is a very hard siliceous killas. The fibrous wood-tin is principally at the sides of the lode, which assumes in the centre a more uniform structure, and incloses fluor spar, quartz, and some mundic."†

Toad's-eye tin, Polberrow Consols—This occurs in minute light and dark brown spherules and mammillary coatings. Many of the spherules are not more than one-sixteenth of an inch diameter, and very few are more than one-tenth of an inch. However minute the spherules, they all exhibit the characteristic concentric and radiated structure. Some of the spots have a dark centre, surrounded with a lighter band, a dark margin beyond presenting a very considerable resemblance to a toad's-eye. Unlike the toad's-eye tin (described on p. 14 of my former paper) from Penhalls, these from Polberrow contain no crystals of cassiterite in their interior and no quartz.

Wood-tin, Penhalls Mine. For this very beautiful specimen I am indebted to Dr. Foster. It is of a general dark gray colour, banded with narrow curved lines of white quartz, alternating with others of grayish and brownish wood-tin. The whole has been at some time broken across and re-cemented with white crystalline quartz. The separate layers of tin oxide and quartz in this specimen are almost inconceivably fine, dozens may be counted in the space of an eighth of an inch in some places (Plate XI, fig. 4.)

This mine is situated on the edge of the cliff on the east side of Trevaunance Cove. Its singular "heaves" were described by the late Mr. John Pike‡ and some of the more remarkable features of the mineral deposits were detailed by my friend Dr. C. Le Neve Foster.§

* *Rep. Roy. Inst. Corn.* 1841, p. 38.
† *Rep. Roy. Inst. Corn.*, 1841, *p.* 38.
‡ *Quart. Jour. Geol. Soc.*, XXII, p. 535.
§ *Trans. Roy. Geol. Soc. Corn.*. IX, pp. 206-9.

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Capt. S. Bennetts, the manager of the mine, describes the occurrence of the wood-tin here and at the neighbouring mine of Blue Hills in the following terms:—"The wood-tin obtained in those mines has principally been found near the various intersections of the tin-lode by the so-called "gossans" (parallel veins having opposite underlie and faulting the tin-lodes.) It is found too in greater quantities near those faults on the borders of good deposits of cassiterite. On one occasion in the western part of the mine, under these conditions large lumps several pounds weight were found of solid massive wood-tin. It is often found in small rounded concretions, occasionally covered with a coating of a friable oxide of tin, (just exactly like putty powder, both in colour and appearance) as fine as the finest slime, and as easily washed off; and again this in some cases is hard as flint, of a pale-straw colour and without any granular structure so far as I can magnify it. I have generally considered this to be a *silicate* of tin. As to the *quantity* of the wood-tin found in this and the Blue Hills Mines from time to time, it is difficult to estimate; but from its being so often met with, and sometimes by no means small in quantity; I should think some tons of it had been met with since I have been connected with the mines."*

Capel, Brookwood (Pl. X., figs 3 and 4). This is a dark granitic capel which was not known to contain tin till it was examined in thin sections under the microscope. It consists of a series of dark-brown and nearly opaque patches, which appear to be composed of oxide of iron and amorphous tourmaline, occupying cavities in what was originally a vesicular rock. Around these, as seen in section, we have a narrow band of quartz crystals with their principal axes radiating from the dark centre. The summits of these are coated with an extremely thin layer (sometimes two or three distinct layers) of wood-tin. The interspaces are filled up with hyaline quartz. The quantity of metallic tin contained in the specimen here illustrated did not exceed 4 lbs. per ton, or less than $\frac{1}{4}$ per cent. Fig. 3 shews the section as seen under the 2-in. power ($\times\frac{16}{1}$), fig. 4 with $\frac{1}{2}$ in. power ($\times\frac{66}{1}$).

Blue Hills, St. Agnes, (Pl. X., fig. 5). This is very similar to the specimen from Brookwood, but the layers of wood-tin are somewhat thicker, and the quartz crystals radiating from the dark patches are also separated from each other more or less completely by layers of wood-tin, in other words the faces of the prisms as well as those of the pyramids are coated with wood-tin.

Wood-Tin, Wheal Vor (Pl. XII, fig. 1.) The stone here illustrated is from a deposit which occurred near that described by Mr. G. M. Henty, and already referred to in my former paper.†

* Private communication, August 12th, 1880.

† First paper p. 7.

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The mode of occurrence of this deposit is thus described by my friend Mr. Argall in the Journal of the Royal Institution of Cornwall.* "The ancient and well known mine of *Wheal Vor*, situate on an elevated plain of chloritic slate immediately East of Tregoning Hill, an isolated body of granite, has, perhaps, afforded more tin ore than any other land of equal extent in Cornwall.

The *Wheal Metal Lode* bears 10°-15° N. of E—S. of W., and like most of the other *lodes* in *Wheal Vor*—dips some 65°-80° N.

Some six or seven years since, traces of *wood-tin* were discovered about 180 fathoms from the surface, west of the *Metal* shaft; and, within a few months, ore of much the same character has been found at some 200 fathoms deep, 80 fathoms further east in the same *lode*, which maintains for some considerable extent an average width of about two feet. Almost suddenly however it attains a breadth of about six feet, and the vein-stone, at the same time, becomes less quartzose, more chloritic, and contains a larger proportion of crystalline tin of the ordinary character. These are sometimes separately aggregated, though frequently they are more or less mixed; but whether the ingredients are earthy or metallic, the *wood-tin* occurs either in scattered grains, in small isolated masses, or in veins of unequal yet always of inconsiderable width; and these--even when no thicker than paper, display the most capricious and complicated flexures, and still preserve a fibrous structure. Both in the broader parts of these narrow veins, and in the small bodies of ore, whether imbedded in ordinary cassiterite, or in earthy ingredients, radiated crystalline, as well as a concentric lamellar structure prevails, the successive rings or cylinders of ore being alternately of clove-brown and of brownish-yellow hue. These aggregations of divergent crystals sometimes enclose kernels of ordinary tin-ore; but now and then they radiate from minute cavities *(vughs)*, which, in such cases are lined with microscopic pyramids of cassiterite.

As wood-tin has been so rarely found in *lodes*, and in no instance yet recorded from so great a depth as in *Wheal Vor*, I venture to hope that the foregoing description of the conditions under which it occurred may not be uninteresting."

It is very dark-brown, has a sp. gr. of 6·32, and contains 1·95 p.c. of oxide of iron. Under the microscope with the 2-in. power, it has the appearance represented in fig. 1, pl. XII, the fibres or needles of cassiterite being intermixed with a little quartz, so as to exhibit the most brilliant colours with crossed prisms. A little colour, no doubt due to interference, is visible without using polarized light at all. The mineral is only translucent

* Vol. IV. p. 255, 1873.

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even in very thin sections. The thin vein and branch shewn represent what looks like an alteration of the brown fibrous wood-tin to ordinary translucent crystallized tin along a narrow fissure. In parts only of these fissures do we see any quartz in particles of distinct size, but minute granules appear to be present throughout the mass.

All the specimens of wood-tin which have come under my notice, including those above described and figured, agree in being nearly opaque, even the light-coloured varieties being much more so than the blackest crystals of tin-oxide. A fibrous-concentric structure is always visible, and, owing to the little adhesion existing between the separate layers and fibres, the mineral is very brittle when cut into thin slices, although it may be tough in mass. The sp. gr. is usually about 6·1 to 6·45, or somewhat lower than in crystallized cassiterite, and it is much more readily acted on by a mixture of sulphuric and hydrochloric acids, as first noticed by Klaproth. Some remarks on its probable mode of origin will be made in a future paper.

Wood-tin of comparatively recent formation.—In the year 1871, an anciently smelted ingot of tin from Tremethack Moor in the parish of Madron, was purchased for the Royal Institution of Cornwall. This block was partially covered with a hard and brittle coating, in some places as much as ¼ in. thick. The brown colour was not evenly distributed, some parts being darker than others, and under the microscope a few shining particles of metallic tin were visible. The specific gravity of the crust was 5·64. I found its composition to be as follows:—

Moisture evolved at 120° C.	6·25 p.c.
Metallic Tin	·43
Chloride of Tin	1·66
Peroxide of Tin	90·62
Peroxide of Iron	1·04
Silica	·41
	100·41

In describing this crust to the Royal Institution, I said "The crust therefore appears to be composed chiefly of peroxide of tin, somewhat resembling that native variety of Cassiterite called "wood-tin," but neither so hard nor so heavy. It has no doubt been formed by the slow oxidation of the outer surface of the block of metallic tin. The slowness of the change is, perhaps, indicated by the dense condition of the incrustation.* A similar sample was submitted about the same time to Mr

* *Journ. Roy. Inst. Corn.*, XIII, 84, 1871.

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Jas. Napier, F.C.S., who wrote of it as follows: "The incrustation which invests the mass of *Jews'-house tin* from Tremethack Moor is a pure peroxide of tin, with a mere trace of iron; in short, the metal has been reconverted into *tin-stone*. This is of exceeding interest, as it shews how pure the metal must have been."*

Similar tin-crusts have since then been placed in my hands from several different localities.

In comparing the crust to wood-tin, I had in view the hardness, specific gravity, and brown colour of the specimen. I have lately, however, cut some microscopic sections from the fragments of the crust still in my possession, and I find the characteristic radiated-concentric structure with a tendency to assume botryoidal forms, in fact the most precise agreement in the appearances presented under the microscope to those presented by ordinary wood-tin.

Pseudomorphous Tin.

Reference has already been made to certain pseudomorphous occurrences of cassiterite in Cornwall.† The most important of these may be here described as follows:—

a. Oxide of tin, pseudo. after felspar.

This is the best known of the Cornish pseudomorphs. Its occurrence in considerable abundance at Wheal Coates in the parish of St. Agnes in the year 1828, was thus described by Mr. Stephen Davey.‡ "Huel Coates is an ancient tin-mine, situated about three hundred fathoms north-west of St. Agnes Beacon. The adit level is about fifty-five fathoms below the surface, and five fathoms above high-water mark. The mine has never been worked more than a few feet below this level.

The crystals in question were discovered in a small vein (composed principally of light-red sand) whose usual width is not more than three inches; but just at this spot it becomes enlarged to twelve inches: they were first discovered about three fathoms above the adit, and continued in the vein to the height of six fathoms, and for two or three fathoms in length; here the small vein was intersected by a large one, about three feet wide (composed of ore-stone and sand, underlying northward about three feet in a fathom) which *heaved* it; and as the mine has not since been much explored, the vein containing the tin crystals has not been discovered on the other side of the larger vein.

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* Ibid.

† First Paper, p. 8.

‡ *Trans. Roy. Geol. Soc. of Corn.*, IV, p. 484. See also Dr. Boase, p. 291, and Mr. 140.

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"The crystals have generally the usual form of felspar crystals; the most common is that of a flattened rhomboid with the angles deeply replaced; they frequently cross and overlap each other. The quantity of oxide of tin contained in them varies greatly, some containing only ten and others as much as seventy-five per cent. Many appear as if they had been broken, and the pieces afterwards cemented together by minute crystals of tin. The crystals first found were small and imperfect; but they increased in size, and became better defined as they approached the centre of the bunch; but from this point a gradual decline took place until they nearly corresponded with those first discovered."

"The veins or lodes in Huel Coates are in soft or decomposed granite or elvan. In this substance similar crystals of a kind of sandstone have been found containing no tin; these occurred on the north of the small vein for the space of two feet in width and fifty fathoms in length."

Referring to some of these crystals Mr. Tweedy says*: "The specimens on the table will exhibit the process of change in various stages, but I would particularly direct your attention to some in which the infused portion of tin-stone has not sufficed to fill the cavity left by the felspar, in which case crystallization has taken place, and the tin-stone has assumed its ordinary form."

The crystals are really twins of the Carlsbad type—some very simple, others highly complex, of four, eight, or even twelve individuals. Some of the more elaborate forms are figured in Groth's *Zeitschrift*† When viewed in thin sections under the microscope the tin is seen in dark-brown opaque masses, usually more thickly aggregated around the borders of the section than elsewhere, but in some occupying the whole of the section, except that there are usually some cavities visible—both angular and irregular. In these, occasionally, distinct though minute crystals of cassiterite are observable.

With the $\frac{1}{4}$-inch power ($\times \frac{150}{1}$) most of the tin still remains opaque and formless, but a few crystalline grains are usually visible. The crystals containing only a little tin are seen to be very unlike ordinary felspar (orthoclase). They consist of irregularly aggregated bundles of minute fibres, just like the substance of the elvan from Trelaver Downs‡ described and figured by me a few years since. The tin begins to shew itself on the edges of the sections as a brown opaque cloud entangled among the fibres, and from this small beginning it can be traced up to crystals in which very little beside tin is visible.

* *Rep. Roy. Inst. Corn.*, 1841, p. 39.

† *Zeit. f. Kryst. u. Min.* 1, plates VII and XVII.

‡ See "On the Trelissick elvan and on a proposed classification of the Cornish Elvans."—*Trans. Roy. Geol. Soc. Corn.*, IX, p. 221.

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In a few cases nearly the whole of the tin replacing the felspar is in a crystalline condition, and then the resulting mass precisely resembles the patches of tin filling cavities after felspar in the Terras elvan already referred to.

The following additional particulars relating to this peculiar mode of occurrence of tin-ore were communicated to the Royal Institution of Cornwall by Mr. Tweedy in the year 1845 :—"The direction of the great lode is nearly east and west. In it scarcely any tin is found, but it carries a good deal of iron and some manganese. The lode in which the pseudomorphous crystals have been found carries its head about 16° south of east, and from its containing a large quantity of sand is called the sand-lode. In fact for a distance of about 25 or 30 fathoms on each side of the point at which it intersects (is intersected by, see Mr. Davey's detailed account *supra*) the great lode, it is filled with a light-coloured sand, containing a large proportion of tin disseminated through it. This sand is commonly aggregated into large nodules or balls, in which the tin crystals are found.....The sand lode also contained numerous fine strings of rich tin-ore running through the sand. The lode had its regular walls, and was at the intersection and for some distance on each side about three feet big, which gradually decreased to about 5 or 6 inches, and as the lode became smaller, instead of sand it was composed of schorl rock with a felspathic base of a light colour containing a good deal of talc (Gilbertite) and a considerable proportion of tin; as the distance from the great lode increased the sandy character of the schorl rock changed, it became more compact and contained less tin."

"The tin-crystals....occurred principally between 55 and 75 fathoms from surface....In the sand lode and in a parallel lode to the north of it masses of botryoidal and stalactitic siliceous black iron-ore containing a very large proportion of manganese with some tin also occurred....in the cavities of these masses, pseudo-crystals of tin occur, which appear as if they had been entangled in the mass of silex and iron....The most remarkable crystals are two in my own collection—one of sandstone, the other of tin, which have been traversed by a vein of iron which has shifted the parts of the crystal on each side of it, in the case of the tin crystal as much as 3-20ths of an inch—the heave appears to have been an oblique one. I have also several of sandstone traversed by minute veins of iron apparently filling up fractures in the crystals."*

The more recent workings at Wheal Coates, on Towanrath lode, have been described by Dr. C. le Neve Foster,† and he states that most of

* *Rep. Roy. Inst. Corn.*, 1845, p. 20.

† *Trans. Roy. Geol. Soc. Corn.* IX p. 211.

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the tin "is derived from the killas on the hanging-wall side. The enclosing rock or *country* is here full of little veins of white clay (*prians*) and cassiterite. Many of the little strings are not thicker than a knife-edge, others ⅛-in. or even 1-in. wide . . . . . the killas is traversed in all sorts of ways by these tinny branches, which extend from two to four fathoms south of the lode. The killas, on the foot-wall side is either destitute of tinny veins or contains very few."

Pseudomorphs of tin after felspar, precisely similar to those from Wheal Coates have been also observed at Carn Brecon* and at Balleswidden mine, near St. Just. †

Felspar cavities filled or partially filled with crystallized cassiterite, or with a mixture of cassiterite and schorl are common in the Terras Elvan already referred to, (see Plate XI) in the felspathic elvans at Belowda Hill (Plate III. fig. 3) and Castle-an-dinas; and in the schorl-rock of Rock-Hill, near St. Austell;‡ as well as in many other parts of Cornwall.

b. Oxide of tin pseudo. after Quartz?

The so-called "Silicate of tin" from Wheal Primrose has been thought to be pseudomorphous after quartz, but the microscope shows it to be of quite a different nature. The crystals are of a grey colour—generally they are groups of rough hexagonal prisms with broken or irregular terminations as shewn in Plate XI. In thin sections the quartz is seen to be filled with minute botryoidal groupings of tin particles, nearly or quite opaque and of a brownish colour. They are in fact enclosed in the quartz, just as we often see chlorite, oxide of iron and other minerals enclosed in quartz. I have only been able to get one specimen of the supposed quartz pseudomorph, but I have little doubt that they are all the same, and that there is no such thing as a pseudomorph of tin oxide after quartz—except of course the well-known natural moulds already referred to as being formed by the deposit of a layer of tin oxide on a quartz crystal. It is indeed probable that any solution which could dissolve and carry away quartz would also carry away cassiterite.

c. Oxide of tin pseudo. after organic forms.

In the British Museum, and in the Museum of the Royal Geological Society of Cornwall, at Penzance, are several fragments of deer's horn containing oxide of tin. A great many of these are said to have been found formerly in the tin stream-works in the Carnon and Pentewan

* T. M. Hall; *Mineralogists' Directory*, p. 131.

† R. Pearce, *Rep. Roy. Inst. Corn.* 1861, and 1863.

‡ "On the occurrence of Achroite at Rock Hill." Min. Mag. 1. p. 55.

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Valleys, and to have been sold to the smelters. The specimens in the British Museum appear to contain a large quantity of tin, but I have not been able as yet to learn what is their specific gravity. In some parts the original horn structure seems to be almost entirely reproduced or preserved in oxide of tin. The specimen belonging to the Penzance Museum has been very kindly placed in my hands by the council for examination, both chemical and microscopical. It is represented on plate XI drawn one half its natural size.

The specific gravity of the whole fragment, and also of a small piece cut from it is 2·7.* Its analysis is as follows:

Calcium Phosphate	80·04
,, Carbonate	2·24
,, Fluoride	·50
Ferrous Disulphide	1·66
Ferric Oxide	·62
Stannic Oxide	2·60
Silica	·22
Organic matter and loss..	12·12
	100·00

It will be seen that in this specimen the amount of tin is somewhat small. It is still however an important constituent of the mass.

The microscopic appearance of the horn as seen in thin sections is represented in plate XII.† The oxides of tin and iron, and the iron pyrites, have found their way to the interior of the bone and are visible throughout the structure, although somewhat more abundant near the periphery than in the interior.

d. Oxide of tin pseudo. after Wood.

Pieces of wood impregnated with oxide of tin are said by many tin-streamers to have been found in the tin-gravels. No such specimens have come under my notice, but I see no reason to doubt their occurrence. I should much like to examine such a stanniferous wood, and perhaps the mention of my desire here may lead to its gratification.

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* The sp. gr. of unaltered (recent) deer's horn (fallow deer) I find to be 1·26, and the organic matter 62 p.c.

† This plate will appear in the next number of the Mineralogical Magazine.

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IX.—*Preliminary Notice of Substances which may prove to be New Minerals.*

By Professor Heddle.

Part Second.

Balvraidite.

I give this name to a substance which may be regarded as of the nature of a hydrated magnesian felspar.

It was found by Mr. Dudgeon and myself in granular limestone, about one third of a mile above and north-east of the hamlet of Balvraid; this hamlet is situated six miles up the Glen Beg of Glen Elg, Inverness-shire.

Only a single large mass containing the mineral was found. In this mass it was associated with blue *necronite* (orthoclase of limestones), Biotite, and a hydrated labradorite.

Its colour is purplish brown of a pale cast; its structure is crystalline granular, it may be called saccharoid; its hardness is 6·; its specific gravity from 2·905 to 2·908

It varied somewhat in depth of colour, but not at all in tint. It had altogether a striking resemblance to *Bytownite*.

A darker and a paler variety were analysed, and gave

	Dark		Pale 1.	2.
Silica	46·041	..	46·165	
Alumina	20·112	..	20·953	22·282
Ferric Oxide..	2·524	..	1·861	1·951
Manganous Oxide	·784	..	·843	·66
Lime	13·472	..	13·254	13·925
Magnesia	8·301	..	7·361	8·2
Potash	1·363	..	1·555	
Soda	2·723	..	3·252	
Water	4·705	..	4·897	4·8
	100·025		100·141	

The last was an incomplete analysis, the silica having been lost.

B. B. it fuses with intumescence and frothing into a vesicular and somewhat pale blue glass.

Examined with the microscope, a specimen taken from the general mass showed no mixture of any other substance, and exhibited no marked

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structure; having merely a mottled appearance, with a slight evidence of minute interpenetrating crystals.

The generally close accordance of three separate portions of this substance shows the uniformity of its composition.

Putting together the alumina and ferric oxide, and the potash and soda, the average composition of the three analyses becomes:—

		Atoms.		Giving.
Silica	46·103 ..	15·37	15·	45·32
Alumina	23·261 ..	4·51	4·5	23·33
Lime	13·55 ..	4·84	5·	14·09
Magnesia	7·941 ..	3·97	4·	8·05
Soda	4·446 ..	1·5	1·5	4·68
Water	4·802 ..	5·33	5·	4·53

These numbers, calculated from the atoms, agree fairly with the analytical results; the atoms of silica also balance those of the bases, without the water. No formula can be deduced from these numbers, however, without a strained grouping of the alkalies with the sesquioxides: though this indeed is little more strained than the present method of grouping them with the protoxides, and the leaving of the water to stand excluded, as if it were always mere water of hydration.

Hydrated Labradorite.

Substances of such a nature are far from uncommon: they are generally set down as resulting from partial alteration.

That presently noticed, which was associated with the *balvraidite*, had anything but an altered or weathered appearance, being remarkably fresh, and even characteristic in appearance.

In colour and lustre it is like bleached wax, its structure is flat-fibrous, resembling thus radiated *Cleavelandite*. Rarely some parts were granular. No cleavage angle could be measured, as the surfaces of cleavage were all curved. Its specific gravity is 2·708.

It yielded—

Silica	49·33
Alumina	26·698
Ferric Oxide	·25
Lime	11·02
Magnesia	·072
Potash	2·59
Soda	5·254
Water	4·845
	100·059

B.B. it frothed like a zeolite, and fused moderately easily to a transparent blebby glass.

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When heated in chips in a crucible by the more gentle action of a Bunsen burner, the chips assumed the lustre of white mica throughout; the lustrous planes were small, and lay in every direction, but chiefly in planes which accorded with the direction of the fibres.

After more intense heating the mineral exfoliated much before finally fusing. Ordinary labradorite does not behave in this manner, and it also fuses with more ease than this.

This mineral is noticed here in order to consider searchingly the question whither *balvraidite* can be a result of a simple combination or fusion of *Biotite by* and *in* this hydrated labradorite.

The facts, as relates to the mode of occurrence, are that plates of *Biotite* are imbedded in *both* minerals.

If any combination could take place between them why did it not take place between the *Biotite* and its labradorite matrix? And again, if *balvraidite* is the result of such union how comes it that there are clear lustrous plates of Biotite still imbedded in it?

Moreover, a chemical consideration will not permit of our drawing the conclusion that *balvraidite* is a compound mineral so formed, inasmuch as such a union of Biotite with the labradorite as would introduce so large an amount of magnesia, would at the same time reduce the lime very markedly; while its quantity in *balvraidite* is, it will be observed, considerably *greater* than what it is in the hydrated labradorite.

TOBERMORITE.

This is a zeolite which I first found totally filling small druses in the cliffs of the shore immediately to the north of the pier of Tobermory in the Island of Mull.

It is massive, or very minutely granular; its colour is a very pale pinkish white; it is translucent; it is frequently surrounded by a thin zone of pale blue massive mesolite. I have never found it in any druse which was not filled to its centre with it, therefore I have seen no trace of crystalline form. It has a hackly fracture, without any trace of cleavage.

It yielded.—

Silica	46·508
Alumina	2·402
Ferric Oxide	1·139
Ferrous Oxide	1·853
Lime	33·404
Magnesia	·474
Potash	1·445
Soda	·356
Water	12·606
	100·187

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The specimen analysed appeared quite pure, that is it contained no particle of the dark matrix.

I next found the mineral in the cliffs near the lighthouse, north of Tobermory, and along the shore towards Bloody Bay. In its modes of occurrence and appearance it was in all respects similar to that at Tobermory. There was here no visible mesolite.

The specific gravity of specimens from this spot, which were larger than those first mentioned, though still seldom larger than a damson, was 2·423.

This yielded.—

Silica	46·62
Alumina	3·895
Ferric Oxide	·664
Ferrous Oxide	1·080
Lime	33·978
Potash	·572
Soda	·891
Water	12·109
	99·81

In proceeding to calculate the formula of this, it is evident that (if not an impurity) the alumina can only replace silica, and the ferrous-oxide lime.

The average of the two analyses and the calculation is as follows :—

		Atoms.		P. C.
SiO_2 ..	46·564	1·552	15·	49·83
Al_2O_3 ..	3·148	·08		
Fe_2O_3 ..	·901			
FcO ..	1·466	·04		
CaO ..	33·691	1·203	12·	37·21
K_2O } Na_2O }	1·632	·03		
H_2O ..	12·357	1·373	13·	12·96

This gives the formula :—

$$3\,(CaO^4,\ H_2O),\ 5\ SiO_2 + 10\ H_2O$$

The mineral thus stands intermediate between *xonaltite* and *okenite*.

It is an interesting fact that *xonaltite* occurs in several Mull localities, some not far distant from the locality of *tobermorite*. This is the first observation of *xonaltite* as a British species.

Before the blowpipe there is no reaction of this mineral which serves to distinguish it from other zeolites.

Last year I obtained it in pieces the size of a small fist, in a quarry out of which the pier at Dunvegan in Skye had been built. It was here also surrounded by a zeolite—which in this case was faröelite.

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The specimens here were finer, and had a more distinct pink hue. *Gyrolite* was seen in some of the adjacent cavities.

Walkerite.

Dr. Walker, Professor of Natural History in the University of Edinburgh, published an analysis of a radiated yellowish-white mineral which was found in diabase at Corstorphine hill near Edinburgh. This is the first of the three analyses which stand below.

In a paper upon British *pectolites*, I introduced this analysis as belonging to these.

Several years afterwards I became the purchaser of the collection of minerals amassed by Mr. Jameson Torry,—nephew of Professor Jameson of Edinburgh. In this collection I found a specimen which agreed with the description of Walker's mineral; this had a label attached, which bore in Mr. Torry's hand-writing,—"From the great quarry, north side of Corstorphine Hill."

I took part of this specimen for analysis. The specimen was a vein, about three fourths of an inch in thickness; this vein was formed of radiating and interlacing lustrous cream-coloured fibres. These fibres phosphoresce when heated, and also slightly when broken.

The mineral had a specific gravity of 2·7, and it lost 1·28 per cent. of water when heated in the water-bath.

Its analysis, on 21·426 grains, is given in the second column. A note was appended at the time, "does not agree with pectolite." The analysis was incomplete from my not wishing further to sacrifice the specimen, in the hope of afterwards succeeding in getting more of the mineral.

A year or two after this analysis was published, I obtained a few chips from the western side of the lower top of the Bin Hill, in Burntisland. I had sufficient only to determine the presence of magnesia in quantity.

Next, I myself obtained it as a fine vein, of over an inch in width, in the *east* quarry of Corstorphine Hill.

Here the vein consists of bunches of diverging fibres or flat crystals, of a high almost pearly lustre, and a pinkish cream colour. The hardness is 4·5. The specific gravity 2·712. It phosphoresces when broken.

The analysis is the third column in the table.

SiO_2 ..	54·	53·215	52·202
Al_3O_3 ..	..	·093	
FeO ..	..	·21	1·335
CaO ..	30·79	26·178	28·635
MgO ..	2·59	6·815	5·12
K_2O ..	..	n. det	·852
Na_2O ..	5·55	n. det	6.504
H_2O ..	5·43	5·228	5·276
	(Walker, 98·36)		99·915

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As it is evident that Walker had thrown down much of his magnesia along with his lime, the last analysis alone is used in the calculation of atoms. It gives—

		Atoms	P. C.
SiO_2	1·74	7	53·71
CaO	1·023	4	28·65
MgO	·25	1	5·12
N_2O	·24	1	7·92
H_2O	·586	2	4·6

The formula may be written thus:—

$$7\,(CaO^4,\ MgO,\ Na_2O,\ H_2O)\ SiO_2 + H_2O.$$

I also recognised in the collection lately belonging to the Royal Society of Edinburgh, three fine specimens—veins nearly three inches in thickness—gathered by Sir George Mackenzie at the Bin of Burntisland, and at Corstorphine; but I could not obtain any portion of these for analysis when the collection was made over to the University.

There being now no question that this, although standing near it, is a substance quite distinct from pectolite, I propose for it the name of Walkerite, after its discoverer.

From Professor Walker, who was a diligent mineralogist, Jameson probably derived his first love of the science.

Walker made several discoveries which have since been credited to others.

From the sixth volume of the "Edinburgh Philosophical Journal," I quote the following, which is probably from the pen of Jameson himself.

"Walker found in 1761 *strontianite*, ore, and ochre of nickel. Plumbum Pellucidum of Linneus, *(cerussite)*, Plumbum decahedrum, *(cerussite)*, and Cyaneum *(linarite)*, both undescribed. Saxum metalliferum of the Germans. Ponderosa aerata of Bergmann *(Witherite)*, and the Morettum, which afterwards appeared to be a peculiar sort of zeolite *(Brewsterite)*. All these were here for the first time discovered in Britain.

Besides, the green, gray, and yellow ores of lead, with other minerals which are rare and seldom met with in other places.

In 1764, the beautiful carnelian marble of Tirey (Tiree); the white marble of the same island, with green transparent schorl *(sahlite)*, the green serpentine, and Lapis Nephriticus of Iona; the green jasper of Rume; the amianthine rock of Bernerey; and the black-lead of Glenelg.

Examined Morvern, and the mines of Strontian. 'There I found several rare minerals, and particularly that singular substance, since called the strontianite, in great plenty; though I had observed it, but very sparingly, years before in the mines of Lead-hills.'

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In 1771 in the mines of Tynandom nothing uncommon excepting a beautiful crystalline ore of zinc (yellow blende.)

Walker's collection in 1822, constructed on his arrangement, consisted of 323 genera—1559 species and varieties,—with duplicates, the number being probably double."

The names within brackets are by the writer.

The so called strontianite of the Leadhills has been proved, by an analysis of the writer's, conducted upon a specimen which can be distinguished by its weight, but not by the eye, from strontianite of Strontian, to be merely a strontiferous arragonite. This specimen was ticketed by Torry "Green Strontianite from Leadhills."

Only those who have explored such places as Rum and Berneray can form a just estimate of the scientific zeal which must have animated the man who did so in the year 1764.

Walker was truly the Father of British Mineralogy.

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Reviews and Notices.

On the Carboniferous Volcanic rocks of the basin of the Firth of Forth, in the field and under the microscope, by ARCHIBALD GEIKIE, L.L.D.,F.R.S.

THIS very valuable communication was read by the author to the Royal Society of Edinburgh, on the 3rd February and the 28th June, 1879. It consists of 80 folio pages with many woodcuts, two plates illustrating the geology of the district, and two (beautifully printed in colours) showing the microscopic structure of the various rocks.

The first part of the memoir is stratigraphical. The author groups the various volcanic rocks into six districts as follows.

1. *Edinburgh district*, including the masses of Arthur Seat, Calton Hill, &c, mostly anamesites, basalts, and porphyrites—erupted about the close of the old red sandstone period.

2. *East Lothian district*, including the Garlton Hills and the coast-hills near Dunbar, mostly porphyrites and claystones—erupted all through the old red sandstone period close up to Carboniferous times.

3. *West Lothian district*, mostly basalts—as at the Binns Hills, Linlithgowshire—erupted chiefly in Carboniferous times.

4. *Stirlingshire district*, including the porphyrites and dolerites, lavas and tuffs of the Campsie Fells and of Kilsyth—erupted in Carboniferous times and probably also in much later times.

5. *West of Fife district*, the Saline and Cleish Hills, Burntisland, &c., with its very distinct lava streams—probably erupted before the Carboniferous period.

6. *East of Fife district*, including the very interesting volcanic vents of the coast near St. Andrews. The author concludes this part of his subject as follows.

"Taking the history of volcanic action as a whole within the basin of the Firth of Forth during the Carboniferous period, we can recognise two distinct types in the occurrence of the rocks,—1st; Successive streams of porphyrite lavas were poured out until their united mass attained a thickness of sometimes more than a thousand feet. Comparatively little tuff was ejected over these areas, except here and there, in the earlier stages of eruption. The lavas now form continuous sheets covering wide spaces of country, and rising into conspicuous ranges of hills. This is undoubtedly the prevalent type of the volcanic accumulations in the Carboniferous system in Scotland. The Campsie Fells in the Stirlingshire district, already described, are only the north-eastern

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extremity of the extensive volcanic plateaux of Dumbartonshire, Renfrewshire, and Ayrshire. The Garlton Hills, in the East Lothian, form a small detached area of the same character, and belonging to the same period; while only about 18 miles to the south-east, on the other side of the Lammermuir uplands, the great volcanic zone of Berwickshire begins with the same kind of rocks, and swells out towards the south-west into the ranges of Roxburgh and Dumfries. 2nd; The other type is almost confined to the basin of the Firth of Forth. It consists in the protrusion of numerous detached masses of tuff, and of various augitic lavas never united into wide plateaux or extensive hill-ranges, but all pointing to local and sporadic action. The four districts in the Forth basin where this type is exhibited may, indeed, be viewed broadly as only one area lying between the two districts of the Campsie and Garlton Hills, which so characteristically exemplify the first type.

The local and independent character of the volcanic activity of the second type may be connected here with another feature, which cannot fail to strike the most casual observer. While the great hollow of central Scotland, between the Old Red Sandstone hills on the north, and the Silurian and the Old Red Sandstone heights on the south side, continued for fully a half of the Carboniferous period to be the scene of extraordinary volcanic activity, the eruptions so far as we can judge, were always confined to the valley. It might be contended that possibly many sheets of tuff or of lava may have been stripped off the bounding hills on either side. But the fact remains, that even were it so, these volcanic materials were erupted from orifices in the valley, and not on the hills. In no case have I ever met with true volcanic necks on the hills on either side of the great central valley.* Denudation could not have removed them; their absence makes it certain that the numerous volcanic vents were confined to the low grounds."

Speaking of the structure of the volcanic masses the author remarks:

"The volcanic rocks associated with the Carboniferous formations in the Basin of the Firth of Forth may be conveniently grouped into four sub-divisions according to their mode of occurrence with reference to the surrounding strata. 1st, *Necks*, that is, masses of volcanic material occupying the space of former vents or orifices out of which the volcanic eruptions proceeded. 2nd, *Intrusive Sheets*, *Dykes* and *Veins*. These are portions of lava which never succeeded in forcing their way to the surface, but after penetrating some way upward, were arrested in their progress, and consolidated among the rocks. 3rd, *Interbedded* or *Contemporaneous Lavas*, that is, masses of molten rock which were emitted at the surface, flowed out there in streams, and consolidated into sheets that lie conformably among the strata with which they are geologically contemporaneous 4th, *Tuffs*, which occur in large stratified masses, or in small beds, either interstratified with ordinary sedimentary deposits, or accompanying sheets of lava."

These different modes of occurrence are then described in great detail.

The second portion of the memoir deals with the macroscopic and microscopic petrography of the district in considerable detail. To this part of the subject the author has devoted much of his attention for twelve years, and we have here the results of this long extended study.

The rocks are classed as Diabase, Dolerite, Basalt, Pikrite (a remarkable

* In the valley of the Nith and its tributary the Carron Water, among the high grounds of Dumfrieshire, necks belonging to the Permian series of volcanoes occur. At the head of Lauderdale, Mr. B. N. PEACH has observed a small neck coming through the Upper Old Red conglomerate, and possibly connected with the volcanic action in which the Berwickshire and Roxburghshire porphyrites were erupted. But in these cases the orifices have been opened in deep valleys among the hills. [Since this was written, Mr. PEACH has met with a number of volcanic necks of Lower Carboniferous age in valleys of the Silurian uplands of Roxburghshire, extending to a distance of at least 10 miles from the edge of the lava-sheets.]

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serpentine-olivine rock), Porphyrite, Felsites and fragmental rocks or tuffs all of which occur within the area in question. This second part of Professor Geikie's memoir should be carefully studied by all petrographers.

J.H.C.

Crystallized Danberite, (G. J. BRUSH & Ed. S DANA, *Am. Journ. Sci.* Aug. 1880). This is a memoir in which the mode of occurrence, crystallographic and chemical characters, optical properties and chemical composition of the danberite of Russell, St. Laurence Co., New York, are described in considerable detail. The form is orthorhombic and very similar to topaz, the axial ratios being as under:—

	c (vert)	$\bar{b}$	$\breve{a}$
Danberite ..	0 8830	1·8367	1·0000
Topaz ..	0·9024	1·8920	1·0000

Seven figures of crystals are given. Some of the crystals are of considerable size, the largest is 4 inches long and 2½ inches wide.

H=7 to 7·25; G 2·986 to 3.021, lustre of crystalline surfaces brilliant, on fractured surfaces vitreous to greasy; colour pale wine-yellow to yellowish-brown; cleavage basal but not very distinct; fracture uneven to sub-conchoidal. B.B. fuses at 3·5 to a colourless glass, tinging the flame green, the bead is milk-white on cooling; in matrass phosphorises on heating with a reddish-yellow light; slightly acted on by HCl, gelatinizes readily with HCl after heating. The following is the mean of four analyses.

Silica	48·23
Boron trioxide	26·93
Lime	23·24
Alumina	·47
Ignition	·63
	99 50

Agreeing very well with the formula $Ca\,B_2\,Si_2\,O_8$. J.H.C.

On the theory of Twin Crystals.—G. TSCHERMAK, (*Min. u. Pet. Mitt.* II. 6. p. 499.) This paper consists of a hypothetical examination of the mode in which twin crystals may be produced, starting from the molecules of the crystals. The author deduces the following theoretical results from his inquiry.

The origin of a true twin crystal is occasioned by two molecules which cohere before they have been able to take up positions of perfect symmetry, the arrangement being such that they have one plane of symmetrical sition, and one axis of symmetry lying in that plane-parallel. Two

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molecules possessing parallel lines of symmetry, but which do not correspond in their lines of growth, form interpenetration twins (like the interpenetrating tetrahedra of Fahlerz, &c.)

In true twin crystals the two molecules stand to each other in hemitrope positions, i.e. one is turned through 180°, but in interpenetration twins they are parallel.

All true twins have their molecules symmetrical to a crystallographically determinate plane, whilst interpenetration twins behave like parallel aggregates. The mechanical production of twins of calcite may be explained by the semi-revolution on the twin axis of the molecules that have been acted on by pressure.

The chief laws regulating the forms of twin crystals are :—

Twin crystals are aggregates of two individuals, which are not completely parallel, but are so placed as to have at least one possible similar plane and one edge lying in that plane parallel in each.

There are three forms of twins according as the two individuals have all the edges in the above plane parallel, or have the entire zone of which the edge and plane form part, parallel, or merely satisfy the above general condition.

A hemitrope position is a necessary condition of true twin crystals.

The axis of revolution is either perpendicular or parallel to a possible plane of the crystal ; in the latter case it is either parallel or perpendicular to a possible edge.

Twins of parallel sided individuals are either directly or after suitable parallel displacement symmetrical to a plane which is either parallel or perpendicular to a possible plane of the crystal, being in the latter case also parallel or perpendicular to a zone.

Twins of individuals with inclined sides are usually asymmetrical. If however the two individual crystals are imagined as being holohedral, the corresponding twin crystal would be symmetrical.

Regular aggregates of crystals obey laws similar to those of twin crystals.

H. L.

Mineralogical Notes by CARL VRBA, *(Czernowitz)* (*Zeitsch. f. Kryst. u. Min., P. Groth* IV. 4).—*Vanadinite from the Obir, Carinthia.*—The author has re-determined the angular elements of this mineral, there being a considerable discrepancy between the previously obtained results of Rammelsberg and Schabus. The author finds the angle $10\bar{1}1 : 0001$ (P : 0P) = 39°·25′56″, whence c = 0·712177, thus agreeing closely with the results of Schabus; he moreover records in specimens from the above locality the forms $(10\bar{1}2)$ $(30\bar{3}1)$ $(21\bar{3}0)$, which have not hitherto been noticed in Vanadinite.

H.L.

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Miscellaneous contributions to Microscopic Mineralogy.—By H. FISCHER, *(Freiberg i. B.)* (*Zeitsch f. Kryst. u. Min., P. Groth.* IV. 4.)—This paper contains the record of a series of microscopic examinations of various minerals, in many of which the author finds more or less impurities, producing variations in the formula of the mineral, e.g. minute cubes of iron pyrites in berthierite. The following is a list of the minerals examined: berthierite, chrome iron ore, incrustations of blende (which proved to be wurtzite), klipsteinite, karpholite, krokydolite, augite from Sicily, beauxite, isopyre, aphrodite, stilpnomelane, lazurite, jadeite, fayalite, monazite, svanbergite, cryptolite, kakoxene, arseniosiderite, and aluminite.

H. L.

Hannayite and Newberyite, by McIVOR, *(Melbourne,) Sitzungsber. der. Nieder-rhein, Ges. f. Natur. u. Heilk., January* 1879. (*previously noticed in this Mag. Vol.* III *p.* 108.)—Hannayite occurs in the guano of the caves at Skipton, near Ballarat. The crystals are 10-12 m.m. long and 1-2 m.m. in thickness. Triclinic:

$$a : b : c = 0{\cdot}6990 : 1 : 0{\cdot}9743.$$
$$a = 122°31' \quad \beta = 126°46' \quad \gamma = 54°10\tfrac{1}{2}'.$$

The forms that have been observed are: (100) (110) ($1\bar{1}0$) (001) and ($\bar{1}\bar{3}3$). Cleavages occur parallel to 001, 110, $1\bar{1}0$, and 130. Color pale yellow. Specific gravity 1·893.

Analyses:—

P_2O_5	45·63	45·77
MgO (with trace FeO)	18·72	19·08
$(NH_4)_2O$	8·19	7·99
H_2O	28·12	28·29
	100·66	101·13

This composition corresponds to the formula:

$$Mg_3P_2O_8 + 2(NH_4)H_2PO_4 + 8H_2O.$$

Newberyite, from the same locality as the last mineral, discovered by C. Newbery; it occurs in large tabular crystals. Rhombic system:

$$a : b : c = 0{\cdot}9435 : 1 : 0{\cdot}9299.$$

Observed forms: (100) (010) (001) (111) (102) (021), the plane of cleavage being 010.

The following is an analysis of the mineral:

P_2O_5	41·25
MgO (with trace of MnO) ..	(23·02)
H_2O	35·73
	100·00

The formula is therefore $Mg_3H_2P_2O_8 + 6H_2O$. H. L.

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On an artificial silicate resembling Orthose, by C. Friedel *and* E. Sarasin, (*Bull. d. l. Soc. Min. d. France* III, 1.)—The authors heated strongly a mixture of silicate of alumina, silicate of potash and water in an imperfectly closed tube, so that the water escaped at an elevated temperature. On treating the dry residue with hydrochloric acid, there remained a coarse powder, consisting of nacreous crystalline plates, which, on measurement, appeared to be Orthose; small crystals of quartz were also produced in this experiment.

H. L.

On the separation of heavy microscopic minerals, by René Bréon. (*Bull. d. l. Soc. Min. d. France*, III, 3.)—In order to separate minute particles of heavy minerals, of different specific gravities, from each other, the author proposes to employ a mixture of the fused chlorides of lead and zinc, the respective specific gravities of these two liquids being 5 and 2·4, so that by properly proportioning the mixture, any two minerals, of different specific gravities, but lying within the above limits, can be separated. The fine powder, to be experimented on, is thrown into the fused chlorides, contained in a conical glass tube, when the particles speedily come to rest, some floating, and the others sunk at the bottom of the tube; the mass is then allowed to cool, and when set, the tube is plunged into cold water, thus cracking the glass. The upper and lower portions of the mass of chlorides containing the minerals can then be removed, and the chlorides dissolved out with water acidulated with hydrochloric acid.

H. L.

On Pseudomorphs. F. E. Geinitz (*Min. u. Pet. Mitt., G. Tschermak.* II. 6. p. 489.) The author maintains his views on the systematic classification of pseudomorphs against those of R. Blum, and proposes the following subdivisions:—

I. Classification of pseudomorphs according to the chemical processes of their formation:

(1.) Pseudomorphs produced without loss or gain of components.

(2.) Pseudomorphs produced by loss of components.

(3.) Pseudomorphs produced by gain of components.

(4.) Pseudomorphs produced by exchange of components, in which the connection between the constituents of the original and the pseudomorphous minerals is still capable of demonstration.

(5.) Pseudomorphs produced by exchange of components, but wanting the above mentioned connection.

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II. The following stages were passed through by each of these pseudomorphs in the process of its formation :—

(1.) Envelopment in some medium that preserved the external form; such envelope either being furnished by
  a. Some foreign substance or incrustation,
  b. Some process of change producing a crust of decomposed mineral, or else it was already present in the
  c. Original envelope or matrix.
  d. In certain pseudormophs, namely paramorphs, an envelope may have been rendered unnecessary by the strong tendency to crystallise ("Krystallisations-Tendenz") of the original mineral.

(2.) Solution and extraction of the original mineral, and an almost contemporaneous, or an afterwards occurring

(3.) Replacement by new substance; either by
  a. Continuation of the already commenced decomposition, or by
  b. Infiltration, more or less independent of the decomposition.

These three stages of formation may either follow each other closely or they may suffer interruptions.

The author holds that there is no true displacement of mineral substance, and objects to the term "displacement pseudomorphs" ("Verdraengungs-Pseudomorphosen) of Blum, preferring "exchange pseudomorphs" ("Austauschs-Pseudomorphosen.")

He finally suggests the following names for the five classes, defined in the beginning of his paper.

1. Paramorphs.
2. Apomorphs.
3. Epimorphs.
4. (4. a.) Partial allomorphs (= a contraction for allassomorphs.)
5. (4. b.) Complete allomorphs.

H. L.

PECKHAMITE (J. L. SMITH, *Am. Jour. Sci.*, *Aug.*, 1880).—This occurs in the Emmet County Meteorite. It has a fused surface of a dingy-yellow colour; when broken, it has a greasy aspect with traces of cleavage, and the yellow colour has a greenish hue; G.=3·23. Analysis as follows:—

Silica	49·50	49·59
Ferrous Oxide.. ..	15·88	17·01
Magnesia..	33·01	32·51
	98·39	99·11

This agrees with the formula $2\,\ddot{S}i\,\dot{R}+\ddot{S}i\,\ddot{R}_2$ "being two atoms of enstatite or bronzite plus one atom of olivine." J. H. C.

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ONTARIOLITE (C. U. SHEPHARD, *Am. Jour. Sci., July*, 1880).—This is a mineral hitherto taken to be Scapolite, but Prof. Shephard finds it differs chemically from Scapolite. H=7 to 7·5 ; G=2·608 ; resinous to vitreous ; contains several per cents of organic matter. Powder very feebly acted on by strong acids. It occurs in small crystals embedded in bluish-grey saccharine limestone and looks like chiastolite. Chemical analysis gives the following results :—

Silica	48·65 to 51·30
Alumina	13·45 to 19·62
Lime	17·43 to 21·60
Titanic Oxide	4·35 to 5·21
Soda	4·35
Potash	1·109
Magnesia	·468

J. H. C.

CASSITERITE (*ibid*).—This occurs at Corsa, Alabama, in crystals smaller than a pea with fragments and grains of tantalite ; one crystal of Yttrotantalite was also observed.

J. H. C.

PARACOLUMBITE (*ibid*).—Prof. Shephard proposes to name the Paracolumbite from Taunton, Mass., Para-ilmenite, since it has "no chemical relation to Columbite.

J. H. C.

STAUROLITE (*ibid.*)—Hemihedral forms of this mineral have been found at Morganton, Georgia, U.S.A.

J. H. C.

FERGUSONITE (*ibid*).—This occurs with Samarskite at Mitchell Co., North Carolina, and is "identical with Rutherfordite."

J. H. C.

PAGODITE (*ibid*).—This occurs of a fine-green colour in Georgia, U.S.A. "It probably forms a stratum of considerable dimensions in a mica-slate formation." It often encloses copper-red rutile. H=3, G=2·86. B.B. turns white and suffers slight fusion ; with borax an apple-green bead. Analysis gave :—

Silica	48 to 52
Alumina	22·6 to 34
Ferrous Oxide	2·10
Soda	5·12
Potash	4·43
Water	3·50

Chromium and titanium not determined.

J. H. C.

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PANDERMITE (C. G. WARNFORD LOCK, *Jour. Soc. Arts*, *Aug.* 6. 1880).—This is a hydrous borate of lime occurring in considerable quantity over a large area near the port of Panderma on the Asiatic shore of the Sea of Marmora. "It occurs in a stratum at the bottom of an enormous bed of gypsum—has been proved for a vertical distance of 45 feet. The mineral exists in closely packed nodules, of very irregular size and shape, and of all weights up to a ton....In outward appearance it closely resembles a snow-white fine-grained marble." J. H. C.

Obituary.

HENRY LUDLAM.—Again we have to record the loss of an original member of the Mineralogical Society, in the person of Mr. Henry Ludlam, F.G.S., who died on the 23rd of June, at the age of 58.

Early a student of the natural sciences, that of Mineralogy became his favourite subject, in which he was greatly assisted by the study of chemistry, which occupied many of the leisure evening hours which the care of an important business allowed him. Aided by an unusually critical judgment he gathered together a large and valuable collection of minerals in which some of the species were conspicuous for their perfection of crystalline form. To these he subsequently added the well-known and important collection which belonged to the late Mr. Charles Hampden Turner, of Rooksnest, Surrey; and also that made by the late Mr. William Nevill, F.G.S., of Godalming. The whole forms certainly the most complete and probably the finest collection of minerals ever made by a private collector. It is now the property of the nation, having been left to the Museum of Practical Geology, Jermyn Street, London.

But Mr. Ludlam was not the mere collector. He had long had in view the desirability of preparing a complete descriptive and crystallographic catalogue of that which it had been his good fortune to accumulate. This great work, to which he looked forward as to a labour of love, was actually commenced by him shortly before the illness which ended in his premature death. The science of mineralogy has thus lost an earnest worker, while his personal friends have to lament the loss of a warm-hearted and true English gentleman. T. D.

W. W. STODDART, F.G.S., F.C.S., F.I.C., &c., Public Analyst for the city and county of Bristol and the county of Gloucester, died of heart disease at his residence, Sneyd Park, Bristol, on the 30th of May last, aged 57. Mr. Stoddart was one of the original members of this society, and he contributed a paper, "on the occurrence of Celestine in the Keuper marls, and its influence on the composition of plants"—to the first number of the Mineralogical Magazine. J. H. C.

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X.—*On certain Crystallized products, formed in smelting operations.*

By W. Terrill, F.C.S.

Communicated by J. H. Collins.

CRYSTALS have often been accidentally produced in the various processes of smelting, having the form and composition, or nearly so, of natural minerals; and have been from time to time described in the scientific journals. Some few, however, which have come under my notice have not been, so far as I am aware, previously described; and as the importance to mineralogy of a due regard to the nature of such crystals, as well as the conditions under which they may have been formed, is beyond question, I avail myself of this opportunity to lay before the Mineralogical Society specimens of the few products to which I allude, and to explain the circumstances of their formation :—

Specimen No. 1 contains some dark green crystals of arseniate of copper, resembling in appearance native olivenite. Before the blowpipe on charcoal these crystals melted easily, then, with a sort of deflagration, gave off copious arsenical fumes incrusting the charcoal, and yielded a button of metallic copper. An analysis of carefully selected crystals gave 62 % CuO, and 38 % As_2O_3 with no water; except for the absence of water and the slight excess of CuO, this is the composition of olivenite. The excess of CuO may be due to adhering particles of the associated black

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oxide. This specimen was formed in the bed of a reverberatory furnace used for smelting copper ores (ore furnace making coarse metal).*

Specimen No. 2 was found in the bottom of the same furnace, and formed under the same conditions as the first mentioned—It is crystalline black oxide of copper, CuO.

Specimen No. 3 is a tin-white alloy of copper and arsenic. In hollow spaces dendritic crystals may be seen, resembling the ordinary artificial crystals of pure copper; an analysis of this specimen gave 76·9 % copper 22 % Arsenic with traces of FeS etc, or nearly Cu_4As.

This alloy was a co-product of a charge yielding a copper regulus of 77 % Cu. (white metal); it separated completely from the regulus, which retained but the merest trace of arsenic.

Specimen No. 4 is the same product as the last mentioned, but having escaped from below the regulus, was oxidized whilst hot, and is covered with a layer of green arseniate of copper.

Specimen No. 5. "Coarse metal" cooled very slowly: in hollow cavities black octahedral crystals have formed which are strongly magnetic. They have only been analysed qualitatively, and they contain copper, iron, and sulphur.

Specimen No. 6.—A piece of ordinary "white metal slag," which cooled and solidified upon a bed of "white metal." The surface which was in contact with the white metal below is beautifully crystalline in oblong patches, each patch being striated in two directions so as to form a cross. The striæ are so fine as to produce a remarkable iridescence.

No 6*a*. is the same slag showing the usual oblique pyramids.†

Specimen No. 7.—Thin lenticular crystals of a clear pale yellow color formed in the bed of a "test" used for cupelling argentiferous lead.

Chemical composition, pure oxide of lead. They were at first brilliantly transparent, but have become a little dull since.

Specimen No. 8.—Acicular crystals of molybdic acid, formed on the surface of a mass of melted regulus whilst cooling in the air, the regulus contained about 5 % molydenum, and the dross, consisting chiefly of these crystals, was found on the surface when cold.

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*The brick work around was considerably cracked, and the vault below contained water for a long time previous to the destruction of the furnace, so that steam could easily permeate the bed.

† This slag is very similar to that described by Mr. Arnold in the *Min. Mag.* vol. III. p. 114. J. H. C.

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XI.—*On the Geognosy and Mineralogy of Scotland.*

By Professor Heddle.

SUTHERLAND.

EVERY writer has his moods. It may be thought that the present writer was cynical and severe in his remarks on the geognostic features of Caithness. With a view to remove any such impression, Dr. Macculloch's opinion of that country is quoted; specially in order that it may be used as a foil to what has to be said concerning the geognosy of Sutherland.

Hear then Macculloch. "On entering into Caithness all the pleasures of travelling are gone and past, for an uglier country from one end to the other would not easily be found. In the usual sweeping manner of those who love to generalise, like Humboldt, it is level, or, at least, not hilly, without trees, without enclosures, as black and as flat as Bagshot Heath; as flat as a pancake! Nature has provided no monuments, and has refused to be its poet. I saw a Caithness forest. It was of mixed wood, of about fifty or sixty years growth, and was precisely five feet two inches and a half high. The surface was so neatly cut and so compact and flat that I might have walked on it. I thought it must have required a large pair of sheers; but the north wind and the east have long arms, and nature was the artist, while the dyke was the scale, and the limit—beyond which the winds had said it should not rise. Such a forest, potted, would have been a fortune to a Chinese.

Liberty is a fine thing, and I do not know that I ever enjoyed it more than here, where I could see the horizon, and felt that I might walk and run and ride in any direction.

The physiology of the country is quite unlike that of Scotland in general. A land scarcely elevated above the sea, a long surf on a smooth flat beach, great pools in the middle of close nibbled grass, sand, and the white tall steeple of Cannisbay like a pillar in the desert, not directing the people the way to heaven, but teaching mariners to shun the land.

The headland of Dunnet Bay is an ugly square mass of red sandstone. Duncanstry Head which rises to a considerable height, is red, square, and ugly.

The lofty pass over the Ord becomes entertaining in descending into Sutherland. Hence, the country begins to look like what it actually is,—*a new creation.*"

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All this monotony has been said to result from the nature of the *one* rock which Caithness contains.

Five rocks, of a facies each differing from the others as much at least in the fashion of their sculpture, as it is conceivable that any stony bodies could differ, are to be seen in the adjacent county—which Macculloch declares to have the features of *a new creation*. Nor does this include the whole;—these five lie on but one side of the country,—the western; passing to the eastern, two others appear; while igneous rocks of three very different natures still further diversify the whole.

There is no county in Britain which contains within it so many formations; hence there is none which can lay claim to so many of the essentials of geologic interest, and none in which there is *a priori* to be expected so great an amount of diversified scenery.

Whatever extent of such expectations may have been indulged in, the reality will here be found to exceed it. *Hills* of all fashions and forms and tints:—*Mountains* which rear their heads like waves which are curling aloft to break, and have been petrified in the poise:—*Rocks* of which the contours are here graceful, there grand; here chaste, there grotesque; but which ever differ each from the other:—*Water* disposed now in deep trenches, and slumbering between gloomy rifts, now sprinkled in innumerable lakelets to the open eye of day, but each standing separate with strangely formed contours, like rain-drops reposing on a polished slab:—*Ocean* thrusting its tongues far in among the sombre hills in shade-loving meanderings; so tortuous, so lost among the land as to accomplish its backwards escape only at the cost of having become half freshened by the long embrace.

What a contrast to Caithness! Here nature has made her mightiest effort as the grand and wonderful; there, exhausted, she slumbrously drew over her the Old Red blanket of actionless repose.

There are many counties which may rival this one in this effect or that grand combination:—there is none which for an instant can compare with with it in a diversity which ceases only when the ocean's verge is reached. Here Old Scotland is in very truth, "the land of brown heath and shaggy wood, the land of the mountain and the flood;" and here, if anywhere, we learn that she is indeed *Old* Scotland; not a recently-created flat-featured parvenu, like others to which she has given a foundation; these dark-green rocks were laid bare, as ocean's deserted bed, ere ever the mountains were brought forth; they have resisted the billow's might during the many successive stages of the world's formation, and have yielded the materials of its after growth.

If anyone could wander amidst the convoluted mazes of its hills without feeling his heart burning within him, it could only be from an utter

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want of sympathy with nature. The lungs play more freely, the stride gets longer, gravitation is an insignificant retardation, the big hammer's weight is scarce perceived; the whole man is improved in tone; even in the midst of nature's warfare, one feels altogether benignant,—so long at least as she refrains from wrapping those grand hills in gloom.

Every geologist must be more or less of an artist; he is none the worse if he be a little of a poet also. And every artist should be more or less of a geologist,—so far at least as to understand the nature of that which he is depicting. And every true lover of scenery should get up his geology well, learning it in the class-room which has an azure dome, or his enjoyment is only that of the moment or of the memory; for the intellect has otherwise nought to grasp; the heart may burn as the footsteps are turned hither or thither, but the cup of rational and reflective enjoyment can only be filled to the brim, while the silent record is being unfolded, the deeper lesson of the rocks being read,—the majestic mystery which is half seen, whole felt.

"It is thus that geology when it quits the trammels of its disputes and its theories, and puts aside its jargon and its trifling, illustrates even the pursuits of the artist. As far as landscape depends on forms, it will be found that it is very often essentially regulated, as to its beauty or deformity as well as its character, by the nature of the rocks of which a country consists. And this is often true, even when the rocks are not visible; as the character of the surface, the outlines of the hills, the forms of the shores, and many other circumstances, depend on the geological nature and disposition of the rocks beneath. Nor is even the aspect of a cultivated country, where all form is either originally absent, or obscured by vegetation and improvement, so independent of the nature of the subjacent rocks as might be imagined. So far from it, many districts have a character in their vegetating surface, if it may so be called, so marked, as not only to indicate the nature of the rocks beneath, but to enable a practical eye to decide where one kind terminates and another begins.

But where the rocks are exposed, the characters of the landscape, as these are affected by their differences, are still more marked; and it is then also more easy to trace the connection between the causes and the effects. In the district which has given rise to these remarks this is very conspicuous; an entire and sudden change of character always occurring whenever gneiss succeeds to sandstone, or the reverse.

I cannot part with this subject without suggesting how necessary the knowledge of rocks is to the landscape painter; not only that he may preserve character and truth in his representations of mere rocks, but that he may avoid those incongruities of general aspect, which do not interfere with the truth of portraiture, or the consistency of style alone, but which

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[illegible] the geologist, which is the [illegible] horizontal and [illegible] mountains [illegible] perhaps they merely [illegible] what that something [illegible] faultless in this particular [illegible] the accident of their having [illegible] than from correct [illegible] anatomy of their landscape.

[illegible] landscape-painting is rare, is a proof [illegible] of knowing the anatomy, [illegible] as well as of his rocks, his [illegible] animals. I do not say that [illegible] theory, or learn to dis- [illegible] must maintain that until [illegible] earth and their character- [illegible] To represent her earnestly, [illegible] it is as vain to hope for [illegible] as to expect to paint [illegible] with their anatomy.

[illegible] landscape painters a [illegible] they will take these things [illegible] arts and sciences materially [illegible] I know of no limits; [illegible] some portion of the con- [illegible] has brought on it, when [illegible] handmaid to the arts of [illegible]

[illegible] was a skilful surgeon, whose caustic [illegible] was asked for. In the belief that it [illegible] transcribing his words of wisdom. [illegible] attempts to depict rocks which are to be [illegible] the writer has often felt that, inas- [illegible] was a prominent feature of Pytha- [illegible] wandering paintless and palletless [illegible] should be a *sine qua non* before the landscape [illegible] their forms and physiognomy.

These remarks find a place here most fittingly, because *here*, that is in [illegible]land, the student of Nature's lineaments will find them assuming [illegible] most marked versatility of expression: and here, as it is well in [illegible] all things to begin at the very beginning, the artist will be able to [illegible] the first foundation-stones of all.

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In the midst of that diversity, moreover, he may imbibe of that inner sence of poetic feeling, without some trace of which, transferred to his ortraiture, no painting can image forth nature's face at all. Unless the eaning of nature's imagery be understood, he had best go back to sign-oards and portraits.

Sutherland is a school-room teeming with studies for both painter and oet. The almost endless diversity of its scenery gives amplest scope for he unfolding of the sympathy which exists between the inner being of nan, and the outer face of nature, and the idealism of the expression of ts features.

The ghastly cheek of Arkle is that of one who knows his next step—the grave. The terrific peak of Coul Beg was surely so *cast* as a conductor to break that livid vapour, and draw the lightning's flash.

The lurid gloom which hangs under the lowering crests of Foinaven, and rolls steaming up that grim trench of Dionard, must surely only lead to the "cold swellings of the dark valley's waters." The tremendous gash, cinctured by Craig Riavach's cliffs, which trends visibly to *nowhere*, can scarce be ought else than one of the Gates of Hades.

Suilven "heaves high his summit bare," the perfect model of a light-house,—for a "Sugar loaf" is never made of *brown* sugar.

Stack Polly is a porcupine in a condition of extreme irascibility; and Coul More, quietly reposing upon her back, teaches Jura a lesson in depicting lines of female loveliness.

It is a most impressive scene to stand on the lonely moor of Lewis, and look eastward across the Minch at those diverse-tinted and wierd mountains of Sutherland. They are wierd and wondrous from afar, but it requires no distance to lend enchantment here. They are wierd and wonderful when they are melting away in blue haze; they are weird and wonderful at every forward surge of the vessel as we approach them—there is no need to place oneself in this position or in that, they are graceful and grand from every side; and they are most wierd and wonderful of all when, twining among their splintered pinnacles, we gaze beneath us into a gulf of mist, and have come to learn that that gulf was once filled with solid stone, and that the great mass up whose slopes we lately toiled, is but a crumbling relic of a vastly greater mass,—one indeed which once stretched both hitherward and thitherward for well-nigh a hundred miles.

The impression conveyed by their aspect from the Lewis is that we are contemplating a sepulchre;—the strip of water lies before us like the wall of a churchyard;—it is just as if we were looking over the wall of a churchyard into a burial-place of the dead. These diverse-tinted cones stand erect like tombstones from a dead level, for all the lower land is sunk. They function as tombstones moreover, for nought but themselves

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[illegible] the life-history of the [illegible] wearing one [illegible] the rule seemed [illegible] great mono- [illegible] from them, after [illegible] which are [illegible]

[illegible] different upon each— [illegible] the deciphering we [illegible] it is not good to come [illegible] the face of that [illegible] we find them coming [illegible] we discover the [illegible] across the summit. [illegible] from base to its acumi- [illegible] now bold, now faint, [illegible] its face alone, but [illegible] upon the back,—each [illegible]

[illegible] writing of the finger is more faint, [illegible] the lines always [illegible]

[illegible] before we are close [illegible] This study requires a correct [illegible] There has been not a little [illegible] as to the second; there has been even but little agreement as to the nature of the stones themselves: and then came the usual result,—individuals carrying big hammers got into the burial-place, and made use of the same in feats of [illegible] muscularity.

It is not, however, the whole expanse of Sutherland, which possesses this plentitude of scenic wealth: the fetter of Caithness' hideousness has crept across the border and far into its centre. To anyone who wishes to get himself into good condition for appreciating scenery, we would recommend a walk from Arscaig, on the south shore of Loch Shin, in the direction of Loch Assin. There are here, certainly, no grand combinations of serrated peak, with finely-contoured slope, with gloomy tarn, or bright-green sea-loch with golden edging:—of bosky dell with glancing river glinting through birken tracery:—or of ocean's foam, with verdant isle and beetling cliff. It may be said of Sutherland *scenically* what has been said of Fife *agriculturally*, that it is "a serge mantle with a golden fringe;" and here we are in the midst of the serge. Roll after roll of

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shapeless humps of heath-clad rock—at least we suppose it to be rock, for it is so enveloped that the hammer's occupation is gone. The very heather is featureless and meaningless :—the short-cropped ling, with scarce a single bell. The ear does not listen to even the companionship of a raven's croak. The pained eye turns in vain for relief, and turning falls, almost with a shudder, upon the vast, Acheron-looking, Loch Shin ;—a great gutter, whose waters resemble flat-porter in shade, and molten-lead in sunshine. Sentinelled, and even they stand far off in repugnance, by the only two ugly hills in Sutherland,—Ben Klibrick and Ben Hee,—it resembles a great junk of a mighty river which has been dammed off at both ends, and left to stagnate ;—an incubus upon nature,—a huge smear upon the face of beauty.

This central district of Sutherland, may be left to the coleopterist, as the only species of naturalist who never lifts his eyes from the ground ; botanist, mineralogist, and artist alike would flee from it, and make for the golden fringe. Bursting southward, he would light upon the greenery of Rosehall, and the sylvan softness of the lower Oikel; northward, he he would pivot among the beauties of the hundred-pictured Tongue, as oft as he could snatch his gaze from the queenly Loyal: or westward, traversing the great gash of the mountains, he would pass between the grand portals of Arkle and of Stack, and enter upon that weird tract, which, stretching from Applecross to Cape Rath, appears to have been the workshop of the Titans, and which presents so marked a contrast to the deadness and drearyness which he has left behind, that he cannot but speculate upon, and search into the causes of so strange and so stupendous a dissimilarity.

By almost all who have written upon the geognosy of Sutherland has the wondrous diversity and the striking features of its scenery been noticed, though no one of the writers has gone very far in attempting to show how it comes that this diversity has been so concentrated in space.

Cunningham says that in the county "every variety of alpine and cliff scenery may be found," and that "it affords, in its undisturbed solitudes, all which constitutes the sublime in nature." Without going so far as to say that every variety of *cliff* scenery occurs in it, the correctness of the statement as regards its *mountains* may be maintained, and it is the ever-varying features which these present, which has impressed the most.

Nicol remarks—"The mountains, rising abruptly from the great table land of lower hills in smooth-rounded cones, spiry peaks, or long serrated ridges, their hoary summits shining in the sun like new-fallen snow, and sending down streams of rugged fragments to the deep sea-lochs that, running far up into the interior, wash their bases, present scenes of wild

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and varied grandeur unknown in other parts of the island. Nor does a closer examination lessen the wonder with which we regard these mountains. They are then found to consist, not of granite or igneous rocks, nor of the older so-called primary strata, crushed up and broken by some great convulsion, as their singular outlines might have led us to expect, but of stratified rocks of no great hardness, lying almost horizontally in thin even beds, and moulded into these strange forms by the slow agency of natural causes."

Speaking of but one type of these alone, Hugh Miller describes them thus:—"Rising over a basement of rugged gneiss-hills that present the appearance of a dark tumbling sea, we descry a line of stupendous pyramids from 2000 to 3000 feet in height, which, though several miles distant in the back ground, dwarf by their great size the nearer eminences into the mere protuberances of an uneven plain. Their mural character has the effect of adding to their apparent magnitude. Almost devoid of vegetation, we see them barred by the line of the nearly horizontal strata, as edifices of man's erection are barred by their courses of dressed stone. Their colours, too, lend to the illusion. Of a deep red hue, which in the light of the setting sun brightens into a glowing purple, they contrast as strongly with the cold grey stone of the gneiss tract beneath, as a warm-coloured building contrasts with the earth-tinted street or roadway over which it rises."

While again, even while confining himself to a small cluster which circles Loch Inver to the eastward, Dr. Macculloch has an ample field for his grotesqueness.—"Round about, there are four mountains, which seem as if they had tumbled down from the clouds; having nothing to do with the country or each other, either in shape, materials, position or character, and which look very much as if they were wondering how they got there. Which of them all is the most rocky and useless, is probably known to to the sheep; human organs distinguish little but stone: black precipices when the storm and rain are drifting by, and when the sun shines, cold bright summits that seem to rival the snow.

"Suil Veinn loses no part of its strangely incongruous character on a near approach. It remains as lofty, as independent, and as much like a sugar loaf (really, not metaphorically) when at its foot as when far off at sea. In one respect it gains, or rather the spectator does, by a more intimate acquaintance. It might have been covered with grass, to the imagination; but the eye sees and the hand feels that it is rock, above, below, and round about. The narrow front, that which possesses the conical outline, has the air of a precipice, although not rigidly so; since it consists of a series of rocky cliffs piled in terraced succession above each other; grassy surfaces of which being invisible from beneath, the whole seems

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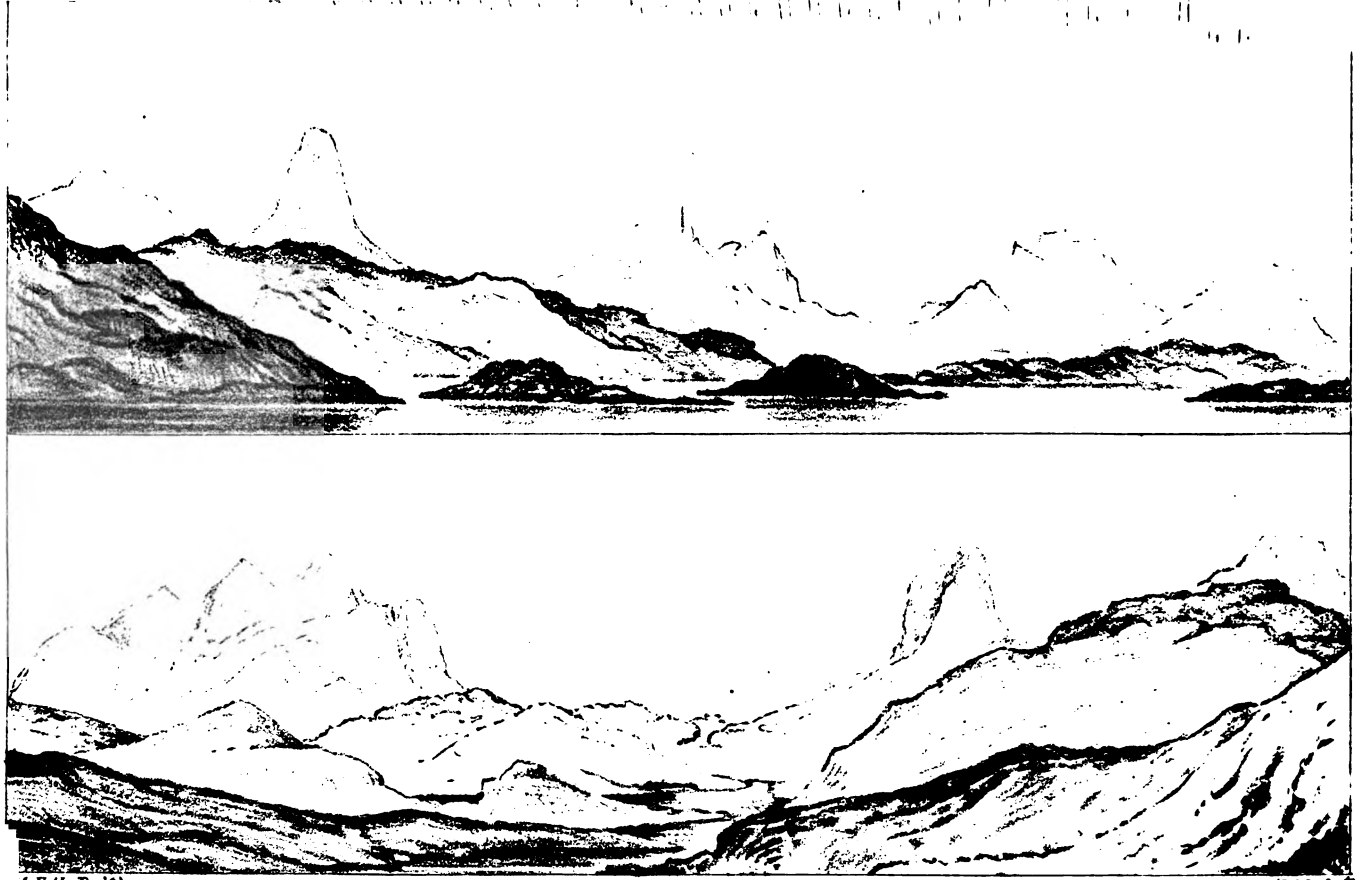

A.F.H. Del.t) (W.I. fec.t)

"Hills which look as if they had tumbled out of the Clouds."

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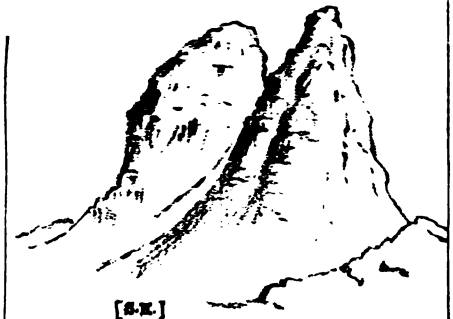

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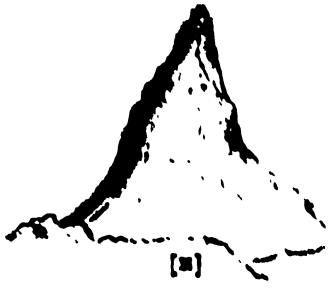

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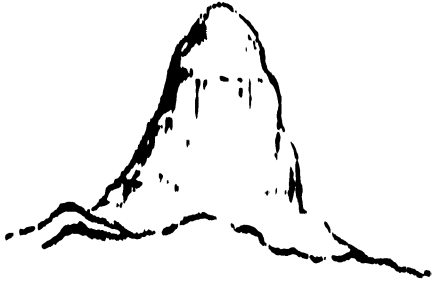

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one rude and broken cliff, rising suddenly and abruptly from the irregular table land below, to the height of a thousand feet. The effect of a mountain thus seen, is always striking; because, towering aloft into the sky, it fills the eye and the imagination. Here, it is doubly impressive, from the wide and open range around, in the midst of which this gigantic mass stands alone and unrivalled—a solitary and enormous beacon, rising to the clouds from the far-extended ocean-like waste of rocks and rudeness.

The conical appearance of Suil Veinn vanishes on a side view. Thus seen, it displays a prolonged ridge with an irregular summit: but the sides all around are precipitous, like the western extremity; and, at the east end, it terminates in a similar manner; looking wide over an open rocky country, and thus preserving its independence in every part. The lateral outline is varied and graceful, the whole mountain, in every direction, presenting an object no less picturesque than it is uncommon and striking in effect." *(See Plates, Gables and Flanks of Suilven.)*

In these descriptions we find one writer startled by the close association of such distinctive forms as "smooth rounded cones, spiry peaks, and long serrated ridges," which alike "rise abruptly from a great table-land." These forms being stated by him to be *quite unusual to the material* which has been fashioned into them; while the agent which has accomplished a work apparently calling for violent effort—"crushing, breaking, and convulsion,"—declares itself as the "slow agency of natural causes."

Another writer gazes with wonder upon a superior quiescence which was unaffected by an inferior turmoil,—a quiescence of deposition so marked that he is carried back to his memories of "dressed courses," rectilinear streets and roadways, and the molecular regularity of "edifices of man's erection;"—"horizontally barred pyramids of mural character" which are based on "rugged hills which present the appearance of a dark tumbling sea."

The last writer makes the assertion that these strange masses have "*nothing to do* with the country or with each other, either in shape, material, position, or character;" while he adds that they "look very much as if they were wondering how they got there."

It is quite possible that *they* know more about that than many of those who have undertaken to tell it us; and it might be as shrewd a surmise to say that they look as if they were wondering how they were *left* there.

The three geologists from whom the above quotations have been made, had, we make bold to say, walked more over Scotland than any three men living,—their remarks show clearly enough that *they* wondered how these hills *got there*, and they may therefore be worthy of the regard of others who may not have seen so much, and thought so much, and taught so much as James Nicol, Hugh Miller, and John Macculloch.

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It certainly would seem to be very specially the function of the geologist or at least of the petrologist to give the earliest lessons in the study of hill and rock sculpture; and certain we are that if such a function were accorded to him, he would select Sutherland as his class-room.

Here he would find the greatest *variety of material* for the operations of nature's chiselings, and here he would be presented with the most ample series of illustrations of *diverse result.* From among these, without difficulty, might he select well-defined types of the various forms of Scotland's hills, which he would broadly classify into her *domes*, her *peaks*, her *ridges*, and her *cliff-fringed slopes.* He would learn with which of these her *butresses*, her *aiguilles*, her *seridans*, and her *scalps* were most closely associated; be able to perceive how it comes that here a rock-mass lies supine in a massiveness which appears capable of defying even the earthquake throw; while there, "worn and wasted to the bones," in splintered pinnacles of precarious poise, its yearly topplings are battering its pediments into shifting sand.

How it comes that upon this hill the mantling sward seems lovingly to shield its rock from the gnawing tooth of the atmosphere; while in that hollow, it palpably is living upon that which it embraces, and eating into it with most insatiate craving.

Perchance he would here, though not so much as in other parts of Scotland, be impressed forcibly with the empty assertiveness, the *pretention* of most of the so-called great hills; especially of those of the ridge and spur type; see how little there is in them after all; what mere skeletons they are—bared of every lineament of life; and as he passed,—balancing himself rope-dancer fashion, along their back-bone ridges, with loose stone slopes, hardly at the angle of rest, which start from his very feet on either hand,—smile at the vanity of the patriotic poet who speaks of the "*everlasting*"—the "*unchanging* hills."

But not in one county, or on one formation, or at one side of a country, can its hill-forms, and their sculpture be learnt;—this can only be attained to—the power of grasping the salient features of any one, can only come from an ever-widening fellowship with all; from winding among their slopes, and scrambling among their corries, till they become almost unto him as familiar friends—ready to picture themselves upon the retina of his memory with easily recognisable sharpness, from every point of view.

A very singular fact, but perchance an easily to be explained one, if we only had the perfectly-fitting key, would then arrest the attention. This is, that very much the greater number of the ridged-hills of Scotland stretch their length from W.N.W. to E.S.E., while their steeper slopes or their cliffs, as the case may be, face the N.E., more or less directly.

From certain geological facts to be alluded to below, this does not apply

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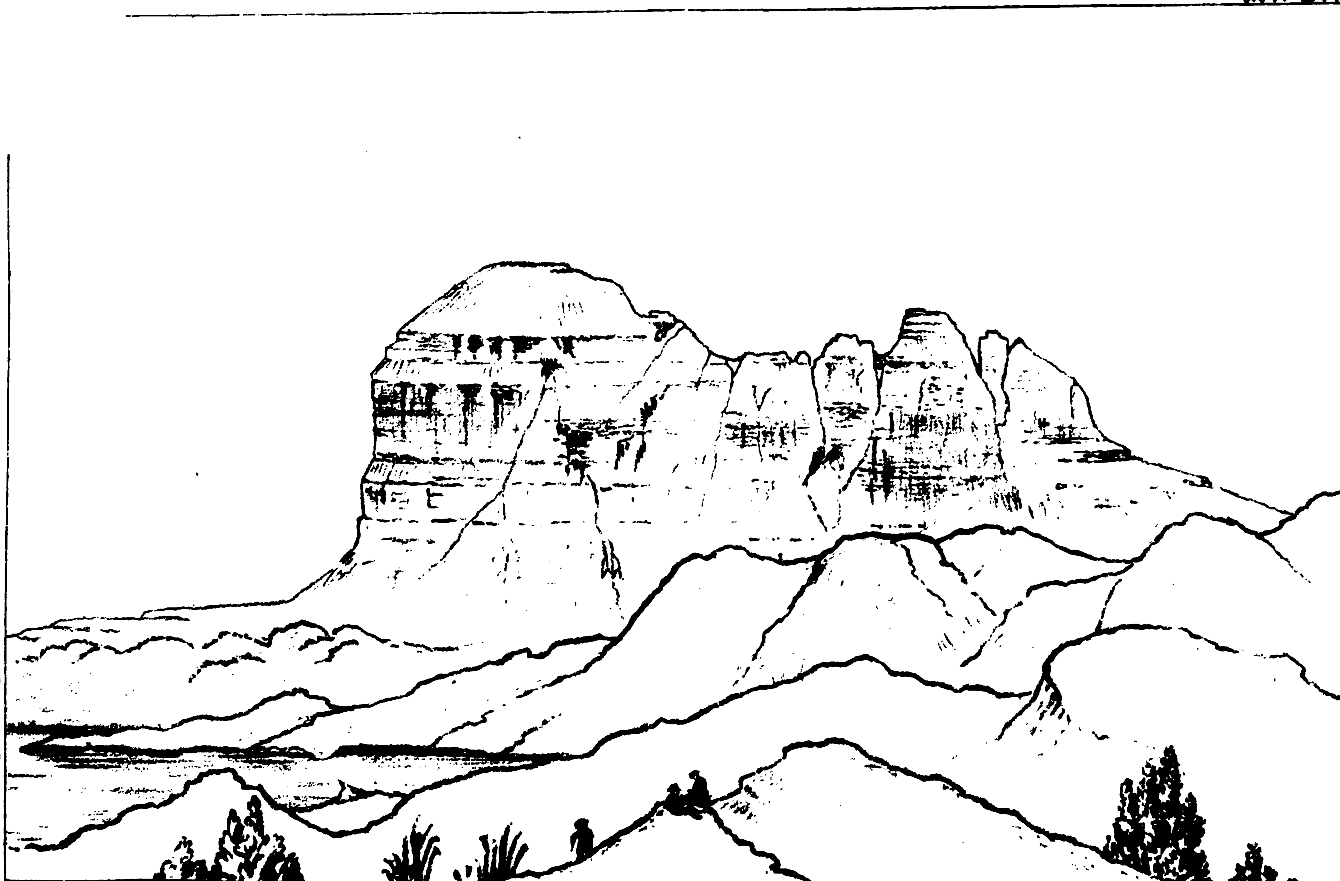

(M.F.H. Del^t)

W.I.J.

to Sutherland to so full an extent as to Scotland generally,—yet it will be seen that—if we except cliff-faces which front the west (and this exception holds in many districts) on account of the rock-escarpments demanding such a frontage,—it does obtain even there.

This singular fact will be fully stated and considered in treating of the Counties in which it is best seen.

The close concentration in space, of Sutherland's *many-faced* scenery has to be accounted for, first, as regards its great diversity in form, and secondly, as concerns its colouration.

In form, it is the resultant of the meeting, almost along one line, of three, it might almost be said of four great formations:—of the rock-masses which form these being acted upon by the agencies of degradation in very diverse manners:—and of that line having been rent and dislocated by a great longitudinal fault,—by a system of nearly parallel transverse faults, and also by occasional divergent rents, which let-in wedge-shaped fragments, in positions which produce extremely contrasted effects among the diverse-tinted rocks. So dislocated, rent, and fragmentary a series of rocks, afforded on account of their opened joints, a comparatively feeble resistence to the assaults of the many agencies, each of which, by its biting tooth is potent as a fashioner of the surface-contour of the land. Assaults of such agencies as the battering of waves, and the scour of whirling tides; of toppling blasts, of the rending expansion of freezing water, of abrading and polishing sand-scourgings, of cannon-cutting rivers, of plowing and rounding ice, of the loosening and gravitating transport of soaking rains,—of all the agencies which hurry the dry land into the great sink of the Ocean,—even as they do at present.

There is abundant evidence that all acted then as now,—then as now leaving upon the frontlets of each rock-mass a tracery of decay, characteristic and diverse as the diversity in substance and in colour of the rock material themselves.

The hills differ also in their forms *on account of the amount of action upon each having necessarily been very unequal*; for the most ancient of these formations has been modelled and remodelled many times, till it is perchance but its wasted pediments which, in low rounded hummocks, alone remain; while, of the more recent, the massive thickness has in many places been but little cut in upon, and still reposes in long stretches of unbroken solidity.

The district to which the above applies has an average width of ten miles, measured from the western shore; and the same general feature of scenery extends as far south as Torridon, though hardly to Applecross.

The rock-pabulum out of which this diverse scenery has been sculptured is highly complex.

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Commencing at the sea-margin, and extending as a pediment beneath all the other rocks, almost to the eastern verge of the district named, there is found the wasted remains of what was formerly, unquestionably, a once great land. At that eastern verge it either sinks beneath the ocean,—is entirely swaddled and concealed by the overlying rocks,—or is cut off from the younger eastern formation by the great fault.

Taking the sea level as its limiting cincture, and stripping from off its surface the overlying masses which now conceal it, its geographical chart presents us with a number of low islets clustering closely, and a single range of peaked hills. These alike stretch from N.E. to S.W; and they present the counter-part of the extended and dissevered tract, which, under the name of The Long Island, lies parallel to them westward of the Minch. A geographical chart of this Eastern Hebrida with its range of great hills is given. Its eastern coast-line is, at its south-eastern extremity, somewhat problematical.

Formed of the same rock, with identical strike of rock-layer, this *Eastern* and *Western Hebridia* unquestionably present themselves as the remnants of a country, the great thickness of whose deposits, as evinced by the almost unvarying continuance of one dip, entitled it almost to lay claim to the dignity of *Continent*.

Out of the sorely-wasted remnants of this ancient land, probably when sinking beneath the waters,—rung-out to give place to the new,—the chisels which sculptured the features of the old-earth crust, trenched a a deep north and south valley, now termed the Minch. This, forthwith submerged, received into its quiet and many-shored waters, layer after layer of comminuted debris, which, consolidated by accumulation of pressure, and agglutinated by metamorphic change, presented themselves upon the returning cycle of elevation, as the many-bedded trough of the Conglomerates. These, from their great dominance in that district, have fittingly received the name of *Torridon standstones*.

It has been said that the vast thickness of strata of the basement rock, vouches for its great extent as a formation. A common profundity of position and similiarity of structure has induced speculative geologists to link it, under the Atlantic floor, with rocks of the Western World, and correlate it with the *Laurentian* of that Continent. It is a more temperate speculation which links it with the Long Island, and rests satisfied with asserting that it is the oldest rock in Britain, and probably in Europe.

The general character of its scenery is most peculiar. Looked at from a distance, its appearance is simply repulsive,—a low table-land formed of insignificant hummocks of bared and barren rock.* Considered in detail, it

* This feature will be seen in the sketch of "The flank of Suilven," and also in the foreground of *one*—the upper—of the sketches of "The hills which look as if they had tumbled out of the clouds." The foreground of the lower, with its gently sweeping curves, consists of the "Upper gneiss."

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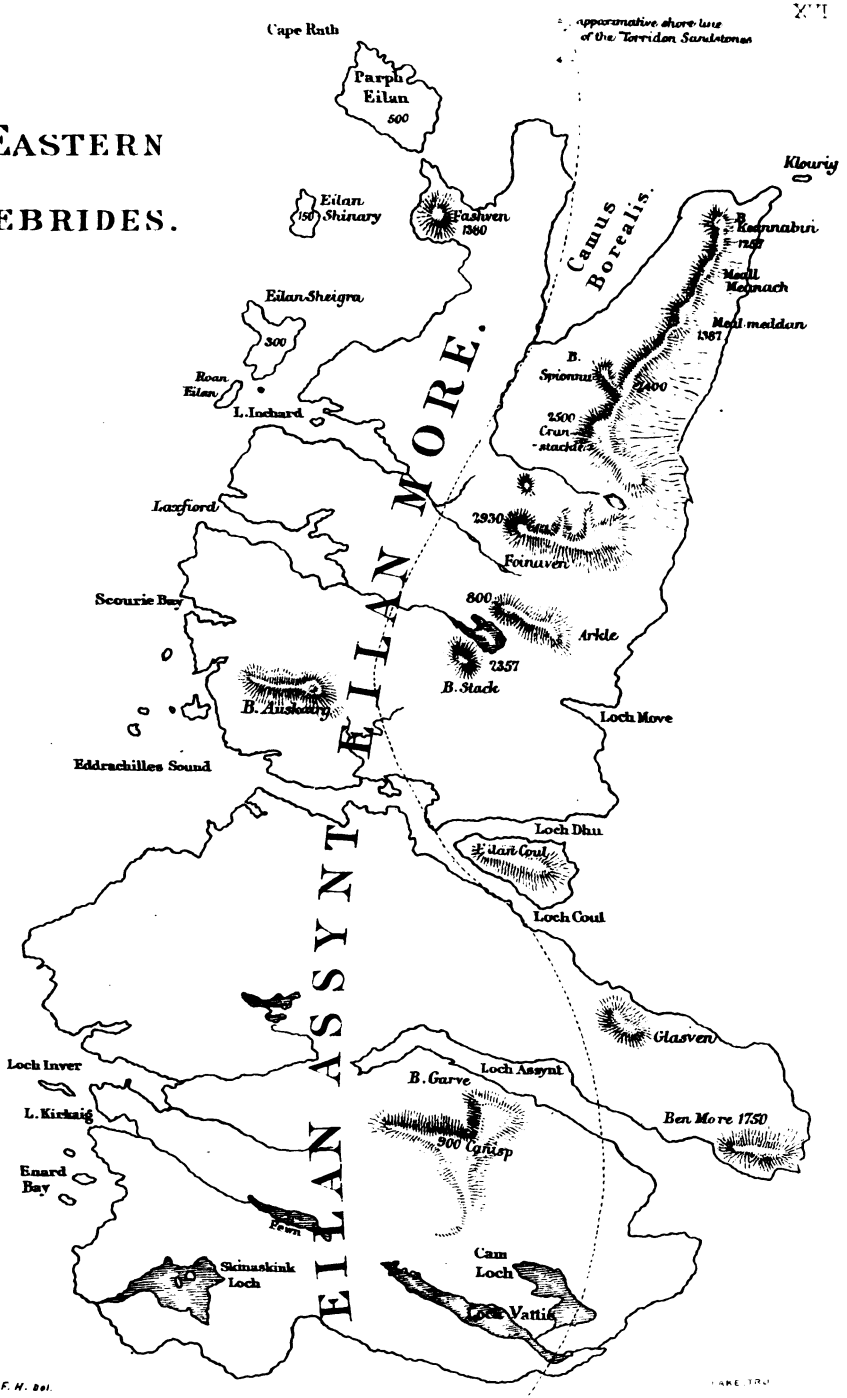
EASTERN HEBRIDES.



M. F. H. Del.

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presents itself as a labyrinth of beauty. Viewed from an elevation and at a distance of several miles, the myriad lakelets which stud its surface confer upon it the appearance of a swamped bog seem from the top of a hill. Fairly judged, as with ever-doubling course we wander amidst the mazes of its lakelets and boskey knolls, we find each one to be an exquisite picture of craggy outline and winding shore, of rockey islet, and rich brown water-tints, and boulder-beach confusion; — of never-ceasing changes of form, and of endless surprises.

It all depends upon time being given to do it justice. Hugh Miller could not see its beauty in presence of the wondrous hills which tower above it; though he happily compares it to "a dark tumbling sea."

Dr. Macculloch, who was as just in his criticisms of scenery as Ruskin is grand, writes of it: "The surrounding country is a melancholy mixture of lakes, rocks, and bays; the general effect of which is as disagreeable as can be well imagined. And yet this air of desolation is to be sought for in the sky rather than on the earth; it is all the effect of climate. When we fairly examine these little lakes, and all those minute details of rock, and bank, and stream, there is not one that is not beautiful, or which at least does not contain the fundamentals of beauty. Were there trees to dispose of as we pleased, I know not of such a collection of little paradises as might be made out of this very country. Nature, I know not why, seems to have reserved her chief beauties for places where she is quite sure they can never be improved or enjoyed."

A walk of three miles—which will take two hours to accomplish—due east of Rhiconich in the direction of Loch Garbat More and Garbat Beg, is a typical one; it will leave upon the pedestrian (if that can be fairly called pedestrianism in which jumping bears to stepping the ratio of 2 to 1,) the impression that in this "melancholy mixture of lakes, rocks, and bays" he has somehow been surfeited with beauty.* The absence of trees, which Macculloch deplores, is not morover, invariable. There are, localities where the rounded swellings of this so called table-land, are amplified into hills of considerable altitude; as in the case of Craig Tolly, at the lower end of Loch Maree, and the grandly opposing pine-clad frontlet of Ben Arrihaar. Here the scenery assumes much of the features which prevail at the Trossachs, being however incomparably grander, and

* At Loch Garbat More the scenery is very grand,—the angling is however poor. Loch Garbat Beg is somewhat tame, scenically, but the angling is super-excellent. In the Visitors' Book at the Inn of Rhiconich there has been written:

Loch Garbat More, I beg you see.
Artist.

Loch Garbat Beg is *more* to me.
Angler.

Those who are "*Heelan*" enough to be able to translate *more* and *beg* will see the point.

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less confined. The birken-clad slopes of Stack, also, are altogether perfect.

Throughout the whole of this "table land" the same feature of rounded knoll-like hummocks obtains; hummocks which in their bared surfaces exhibit the denuded edges of high-tilted strata, while their curvilinear outlines vouch for the fact that, whatever combination of agencies had effected the enormous amount of denudation which such an extent of shorn-off outcrop vouches for, polishing ice had been the agent which ultimately had conferred upon them their characteristic forms.

That the ice sheet which had effected this was of no great thickness is disclosed by the multiplicity and abruptness of the curvatures; there palpably had not been weight sufficient to grind all down to anything of a uniform level; rending and regelation of the sheet must have been incessant.

So much for the *subœrial* scenery of this wasted formation;—a troubled sea of heaving but *not curling* billows;—sombre coloured, lake besprinkled, ice worn;—weather-wasted when it lifted its head above the waters; swaddled in shingles, and over and above these swathed in sands and silts, when it was depressed beneath them. Re-elevated and again depressed, but with each subœrial exposure subject again and yet again to the many biting teeth of atmospheric gnawings, as each superincumbent and protecting belt was cut through, in that unceasing process which abstracts from the pre-existent, materials for the construction of the new.

But the formation has a *subterranean* scenery, as well as a subœrial.

Murchison, while denying that the formation anywhere showed itself to the eastward of the over-lying quartzite, admitted that it might in some undiscovered locality be "brought up,"—that is, *eruptively* brought up—even far inland to the east.

But it *is* "up"; that is, it is *surface-exposed* to the east of the quartzite, without having been "brought up." "Up" even in cliffs of over 1000 feet in height, and *so* up because *there* it was never ground down; remaining still as a range of lofty hills, the highest peaks of all the old islands of either Eastern or Western Hebridia.

There they remain, because they were swaddled up during one of the dips which Old Scotland took beneath the waves; and they are seen only where the swaddlings have been much thinned off, or altogether removed. A dome-shaped eminence which now forms the main bulk of Fashven protruded in the N.W.; and a range of peaked summits extended from Kean-na-bin to Ben Stack in the east, when the formation stood with bare head beneath the aerial dome. Of this range what is now the western peak of Foinaven forms at present the culminating point; this has an attitude of 2952 feet; but, as two outliers of quartzite of about 25 feet in

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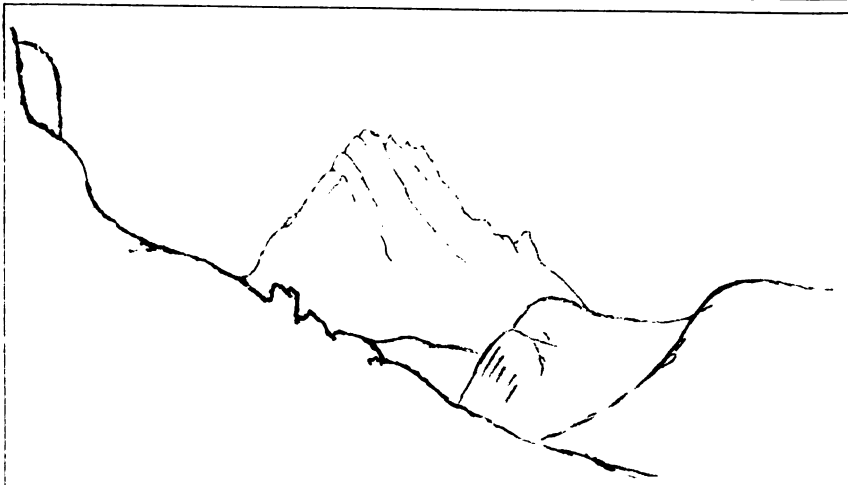
BEN GRIAM BEG. OLD RED SANDSTONE.



BEN STACK. HEBRIDIAN GNEISS.

M.F.H. Del.

LAKE, TRUR

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thickness repose upon the highest point, 2930 feet (Keanngarbh) is now he highest elevated point of Hebridia which remains.*

Of the features of this alpine range of the old continent, the thinness of the cover which inwrapps it, permits it to be disclosed that the summits were of peaked form. From one indeed,—Ben Stack, of which an outline sketch is given,—the cover has been totally denuded, at least at its highest or western summit; and it towers in isolated pre-eminence over the plain,—a haystack-gabled hill.

We may not do more than suggest that even this old formation had its N.E. cliffs; for, though it is probable that great part of the stupendous precipice which, from the N.E. front of Keanngarbh, depends over Corry-Dual, had been formed in that ancient day, and had posteriorly been sheathed in the more recent deposits, still it is possible that it may have been partly cut-out by more recent denudation.

It is a strange history which this mountain range of Eastern Hebridia aids in unfolding. An almost continuous line of peaks dominates nigh 3000 feet above a table-land; peak and table-land alike being carved out of the high-tilted edges of the strata; and, as the range of hills runs across the strike, these peaks owe their existence to no folding of the crust; and there is on neither side of the range the smallest evidence of local fault,—of either upheaval or depression.

The table land must have been formed by the cutting away of the rocke westward of the range.

What cut it? and when was it cut? It has been already shown that ice was its *most recent* cutting tool,—ice which simultaneously had cut-in upon the more recent of the local rocks;—but it was also pointed out that the hummocky feature of the plateaux indicates but a *small thickness* of ice. This *recent* cutting then could not have effected the great and general abrasion; and that it did not do so, but that the great table-land was formed when Hebridia stood *a formation by itself*, is proved by the fact that the succeeding formation *lies upon*, and rears its sculptured hills *from that levelled but gently undulating table-land.*

What then had shorn away the land, so as to form the great flat plateaux?

Not atmospheric agencies,—the rock everywhere still shows itself as a most unalterable one. Not breaching waves,—sea cliffs are nowhere visible

* Our fellow member, Mr. Colin Phillip, tells me that, from the altitude which he attained upon its western slopes, he was able to see that the summit of The Maiden,—a hill which lies north of Slioch, consisted apparently of the "old gneiss," and was either that rock or the "igneous rock" of the great fault,—(afterwards to be noticed).

If this be so,—and I have great confidence in his experienced eye—then, as the Maiden is about the height of Slioch, and certainly over 3200 feet, *it* must be the highest peak of the old gneiss. Cleesham, in Harris is, by the author's measurement, 2,785 feet.

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upon the flanks of the range, which are of curvilinear outline. Not the scour of waters; no river trenches, with sloping banks which eat back into the land, are anywhere to be seen,—the plain is a great flat, and the lake-hollows are all primarily occasioned by *recent faults*,—as will be afterwards shown.

Ice, alone of nature's agencies, remains to accomplish it; ice, engendered among the lofty eastern peaks. The presumptive evidence is strong; actual evidence is in several localities available. Upon precisely the same grounds that we assign the rounded forms and curvilinear outlines of the rocks in the throat of a pent-up mountain-gorge to the grinding passage of ice, are we entitled to hold that ice cut away *at least the surface* of the low land from which the great landmark hills of the Torridon Conglomerates rear their banded cliffs. For beneath the pediment-strata of these towering masses, do the sweep of curvilinear outlines and broadly-rounded forms pass.

It is true that the sweep of these is more gentle and less abrupt than that of the more recent graving, but the character is the same. Nor is it the very lowest land alone which would appear to have thus been subject to the sway of this old ice; for one of the localities where *ice-sign* is best seen is upon the outlying hill of Fashven; where, *upon every side* upon which the junctions can be seen, sweeps, which would give the lower rock a dome-like form, seem to glide under the mantling-cap of Conglomerate.

The same is to be observed upon the north side of the gneissic islet at Sandwood,—east of the lighthouse at Cape Wrath,—the south-eastern foot of Suilven,—the head of Loch Veyatie,—and, in a most suggestive form, to be afterwards considered, at what I will call the *south terrace* of Arkle.*

This range of hills then, among whose peaks was cradled the *nevé* of an ice-sheet which swept westward, lay some ten miles from the present western shore. There is evidence to be seen upon the western shore of Loch Erribol, that the old land did not extend much further eastward, unless it so extended at a great depth. In this direction it may, for purposes of a newer formation, have been all used up; but close to this the great fault comes in, and no portion of the old formation has been found as yet (even "*brought up*") to the east of that. Be this as it may, the summits of these dark-tinted hills, with grizzly cliffs, vertically seamed by the junction-lines of the contact-beds, protrude themselves, in conse-

* Since the above was in print, I have read a report of Professor Ramsay's address to The British Association, on the occasion of its Meeting at Swansea. In this he says,—"I received a letter from Professor Geikie, in which he informed me that he had discovered mammillated moutonnée surfaces of Laurentian rocks, passing underneath the Cambrian Sandstones of the north-west of Scotland, at intervals, all the way from Cape Wrath to Loch Torridon, a distance of about 90 miles."

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quence of the action of degradation, through the thinned-off beds of an overlying rock. One which, in the case of the loftiest summit, is as remarkable for the lightness of its tint, as is the protruding mass for its sombre tone.

This great hill of Foinaven, though seemingly of quartzite, is in its bulk formed of the old gneiss;—thinly in its western, thickly in its eastern portions mantled by quartz rock. Formed of a narrow west and east ridge, which extends for some miles, it to the northward throws out several spurs. Over both slopes of these, the many-jointed enveloping rock throws down myriad fragments, which in white streams streak the darker gneiss. The hill seems to be perpetually swathed in snow, and, as it dominates with strangely serrated ridges over the sun-forsaken valley of the Dionard, this composite mountain, the loftiest peak of the oldest world in Britain, may be aptly termed the Grizzly King.

Being a composite mountain, we are not entitled to say more of the form which atmospheric sculpturing would confer upon the material of which it is most largely composed, than that its western peak, with uniformly steep slopes on three sides and a rough precipice upon the other, warrants the conclusion that, at least with high-tilted strata, *acutely conoid forms* would prevail.

We do not even in the isolated mountain of Stack, obtain conclusive information on the point, for this pyramidal hill unquestionably owes its form primarily to faults. One of these can be seen from Loch More, running directly up the eastern gable; and it will be found upon the summit, cutting the hill longitudinally in two, almost along its narrow ridge; while its grandly-precipitous northern face,—than which nothing in the way of rock-belted hill-side can possibly be finer,—is evidently the south flank of the fault which formed Loch Stack.

Though, from the encumbered state of the hills of this range, we learn little of their sculpture-forms, still the limits and the nature of the encumbering rocks disclose something of their history.

The sadly-worn and shrivelled bulk of the first firmament sank beneath the waters. We now enquire how deep did it sink?—and did it descend horizontally, or turn upon an axis? as Norway is known to be doing at present, and as there is good reason to believe is Scotland likewise.

The mode of swathing of the table-land, and mantling of the hills, may answer these questions.

The lower flats of the table-land were all covered up; bed after bed of coarse-grained grits were showered down upon the bottom, till they attained a thickness which in Teallich attains an altitude of 3486 feet; and, judging from the continuence of the same dip westward, a probable thickness of over 6000; they welled up over the higher hunches till

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they capped Fashven, but their thinned-out edges nowhere reached even to the foot of the great eastern chain.

An after denudation, and a still posterior mantling, renders the point somewhat obsure,—but, *somewhere a little to the west of the foot of the mountain range*, would seem to have stretched the eastern shore-line of the Torridon Sea. By a bit of its western, its deposits hang on to the Eye Penninsula of Lewis;—denudation would seem a second time to have cleaned out the scoop of the Minch.*

But the pebbly deposits do not now lie parallel with the present horizon floor; in Sutherland for the most part they dip some 5° to the E.S.E. There is evidence neither of fracture with elevation on the westward, or of fracture with depression to the eastward. The purely local evidence would indicate that Eastern Hebridia had turned upon the axis of its eastern shore, and in sinking beneath the waters had "taken a header" to the west. It is much more probable however that lateral pressure had depressed the trough of the Minch at its centre, and that this had been succeeded by undue local elevation. One thing is evident, namely, that when the old land was again elevated above the waters, burdened by the eastern shore-belt of the Torridon deposit, its great range of mountains had still no covering; and that these, with an altitude more elevated than their present, had for a second epoch to submit, and partially to succumb to the assaults of wasting rains and warring elements.

Were the *Torridon sandstones*,—the formation which had been laid down in this old ocean bed,—now presented to our contemplation in the unbroken and rectilinear bands in which they were originally deposited,—nay, were they even seen either in transverse fissure, or longitudinal escarpment, it is questionable if anything would be considered more tame, and scenically repulsive. What we do see of the formation, as the remaining fragments of a once vast deposit, is very different:—it is as enthralling as a spectacle of scenic magnificence, as it is overwhelming to the intellect as an example of stupendous denudation.

The bands of barred stone which are seen passing from north to south across the terminal faces of each individual fragment of the formation, stop abruptly on their shorn-off cliffs, to be taken up again at the self-same altitude by the face of the next fragment, standing as it does even miles apart. Nothing could vouch more imperatively for these miles of empty air having once been filled up with linking stone. It appears as if a mighty ploughshare had been dragged from east to west across the huge belt of rock, and had hurried all but a few fragments into the waters.

*The Minch is in the direct line of the Antrim,—Shiant,—Faröe, volcanic outburst. 't may be a fall-in.

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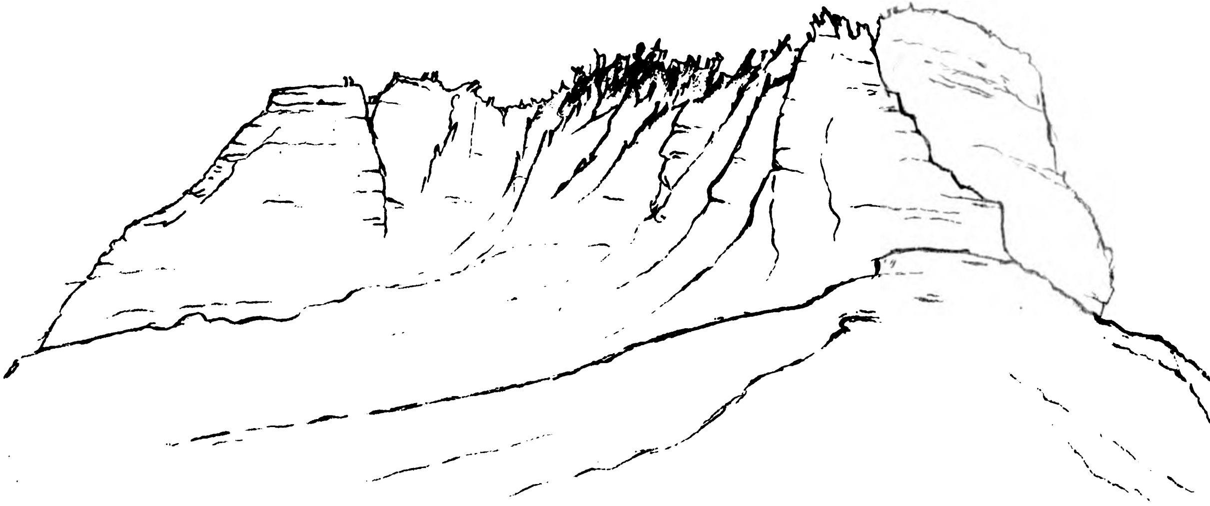

CREST OF STACK POLLY.—CONGLOMERATE.

M. F. H. Del.

Lake, Truro.

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Carved out of a mass above all others formless and void, these fragments stand isolated,—fantastic beyond measure. Scenery hunters have been said to "*rave*" about the splintered pinnacles of Coruisk, but these monolithic hills of Coigach have ever struck the beholder dumb.*

Fashioned from a material as unvarying in its mass as clay, they confront one another, no two the same; differing so absolutely in their every feature, that as another and another is seen to separate itself from the line, wonder at the endless diversity of form usurps the place of admiration. (*See the sketch from Handa.*)

And when the nature of the chiseling is examined, that wonder culminates.

There are but two stages of the process;—the opening of rectilinear jointings in the rock-wall, and the falling asunder into sand of the constituent granules.

That the ploughshare found a ready entrance is palpable; for a series of great transverse faults, with occasional uphevals and subsidences, rent the great belt of rock into isolated fragments; the looser or the softer portions of which have been swept into the ocean.

It would seem to be a common opinion that ice had been the agent of transport here; but the sea-cliff aspect of many of the rock-fronts, indicates wave-action.

The most isolated of these hills, that called Suilven or the "Sugar-loaf," is usually regarded as pre-eminent in peculiarity; but, as illustrating the modes of their sculpture, that is, the processes of degradation of the rock-mass itself, and indeed even for its general form, the rocky shaft called Stack Polly must take precedence.

Dr. Macculloch is of the same opinion, (he errs in calling it *Coul Beg* however.) He says "It is even more remarkable than Suilven, while its form is more elegant and versatile. In every view it is as graceful and majestic as it is singular; and like the other mountains of this extraordinary shore, it has every advantage that can arise from independence of position; rising a huge and solitary cone, from the high-land beneath, and lifting its dark precipice in unattended majesty to the clouds."

Certainty the most marked feature of these mountains of Torridon sandstone is the vastness and truly *mural* character of the precipices which girdle them, frequently upon several of their sides; this feature has been accounted for by Nicol, who writes,—"The beds have been vertically divided by a rude prismatic structure, and the projecting

* "The other side of Chaos," was the expression of one upon his return, *solemnised* by an early morn's first inspection of them.

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[illegible] cathedral, carved [illegible]

[illegible] and in Stack Polly, the [illegible] which a flat-bedded and [illegible] less wonderful feature.

[illegible] connecting, [illegible] and angle had been [illegible] of Omnipotence [illegible]

[illegible] as they seem regardless [illegible] of Heaven alone could [illegible] is actually being [illegible] portions [illegible] these are dis[illegible] both its slopes, [illegible]. The [illegible] so that we are [illegible]

[illegible] of the hill [illegible] pinnacles project [illegible] of human forms;— [illegible] or tearing down. [illegible] there, they bend [illegible] they seem to stoop [illegible]

[illegible] over the scene, and we [illegible] of nature, and the [illegible] nightcap of the [illegible] the tempest, [illegible] of man. The [illegible] malefactor; but [illegible] images are only [illegible] and our sympathies [illegible] in the *form* of man, [illegible] warfare of Atlantic raggings. [illegible] and windowed raggedness," to [illegible] the earth they came, must they endure the pelting of every pitiless storm.

The wierd spectacle is now seen only in fitful glimpses;—as we grope among the spectral shapes, the [illegible] is almost overpowering. Starting forth from out the whirling scud, now distant and now near, [illegible]dows bulk gigantic on the gloom cast from the great square

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ROCK SCULPTURE ON STACK POLLY.

M. F. H. Del.

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ROCK SCULPTURE ON STACK POLLY.

N F H Del

LAKE TRUBO

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towers. Soaked by condensing fogs, and chilled by eddying blasts, we feel as if it needed but one touch of those grim gaunt forms to root us in their midst. (*See sketches of "Rock Sculpture on Stack Polly."*)

We are presented here with an illustration, perhaps the most striking in Scotland, of the extreme diversity in external modelling which may, in the different stages of their operation, result from the action of the same agents upon the same rock.

The opposing massive western dome of Suilven, and the ridge of Stack Polly, are altogether as far apart, as types of rock sculpture, as can be conceived. But "even to this favour,"—in similar fashion, must Suilven rot at last. It is the destiny of the everlasting mountains to "change their shapes and flow from form to form," being mere ephemeral embodiments of substances of many destinies,—a pabulum for the operation of unseen forces moving in ceaseless cycles.

Perchance it is through the very intensity of the impression of the *finite side of nature*, as here evidenced, that we are, by a kind of revulsion—when we consider it in relation to the register of time—overpowered with the sense of what has been called its *infinite side*;—"that side which yields no response to man's yearnings, and refuses to make itself plastic under even the strongest powers of emotion. For outside of and beyond man, aloof from his warm hopes and fears, his joy and sorrow, his strivings and aspirations, there is the vast immensity of nature's forces, which pays him no homage, and yields him no sympathy.

This aspect of nature is nowhere borne in upon man as in the presence of the great mountains, which seem so impassive and unchangeable. Their strength and permanence so contrast with man, of few years and full of trouble—they are altogether heedless of his feelings or his destiny. He may smile or weep, he may live or die; they care not. They are the same in all their on-goings, come what may to him. They respond to the sun-rises and the sunsets, but not to his emotions. All the same they perform their mighty functions, careless though no human eye should ever look on them,"—caring nothing, what strange story he may tell about their birth. Suilven will never bow his head to listen, nor Quinaig shake his sides in mirth, or Coul Mohr shed a tear.

They keep their own secrets and drop no hint to him; his grand co-ordinations, his miserable squabblings, his pettiness and his pettishness are to them less substantial than a wreath of vapour, and affect them not at all.

Considered as individual *monolithic hills*—and there are none in Scotland to which the term so fittingly applies—their character is that of an extended narrow cliff-faced ridge with gable ends.

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They are occasionally precipitous upon every side.

Sketches have been given to show the changing features of gable and of flank. (*See "Gables," and "Flank of Suilven."*)

Sprinkled at somewhat irregular distances in straight line, at but a short distance from the shore, they stand like a line of sentinels to guard the land: and when we place ourselves, as at the Island of Handa, in such a position as takes in an extended sweep of the line, we perceive that they must be but the fragments of a continuous belt of escarpment, or perchance shore-cliff.

The western frontlet of Quinaig almost proves this. That cliff-face has nearly, but not entirely, been cut up, and still remains continuous as a far-extending rampart. The second sketch of Quinaig from the south, shows the diversity of outline which even one *and* the same hill can exhibit. Its north-eastern frontlet displays a precipice so intricate in detail and magnificent in form, as to be beyond the powers of an ordinary pencil to depict. Of Coul Mohr, the grandest and most versatile of the whole, it can only be said that it would take many wanderings before we could "tell of its high towers."

Perhaps their versatility is nowhere better seen than in Suilven, when viewed from the north; whence the thinned off ridge has assumed a skyline which is closely imitative of that of the rough lower rock,—as shown in the sketch.

The isolation of these fantastic hills—their standing so far apart from the high ground of the interior—the strange toning of their purple colour—and the marked contrast between their rectilinear courses and the fretwork roughness of the pediment upon which they stand, form the *first element* of the *diversity of the scenery* of the hills of the district.

In order to be in a position to speak to the *period* when the gateways were cut through the Torridon formation, and the pediment of older rock laid bare betwixt them, we must question the next formation.

What it cost to cut Suilven.

Reference has been made above to the finite side of nature, considered in relation to the register of time; and we have in this district, indeed in this formation, a more palpable record of the *first*, than in any other part of Scotland. We have now to see if we can in any way, or in any degree, definitely consider it in its relation to the second,—the register of time.

The ridge of Stack Polly was selected as exhibiting the greatest amount of ruin; and, as the accuminating processes of decay have cut

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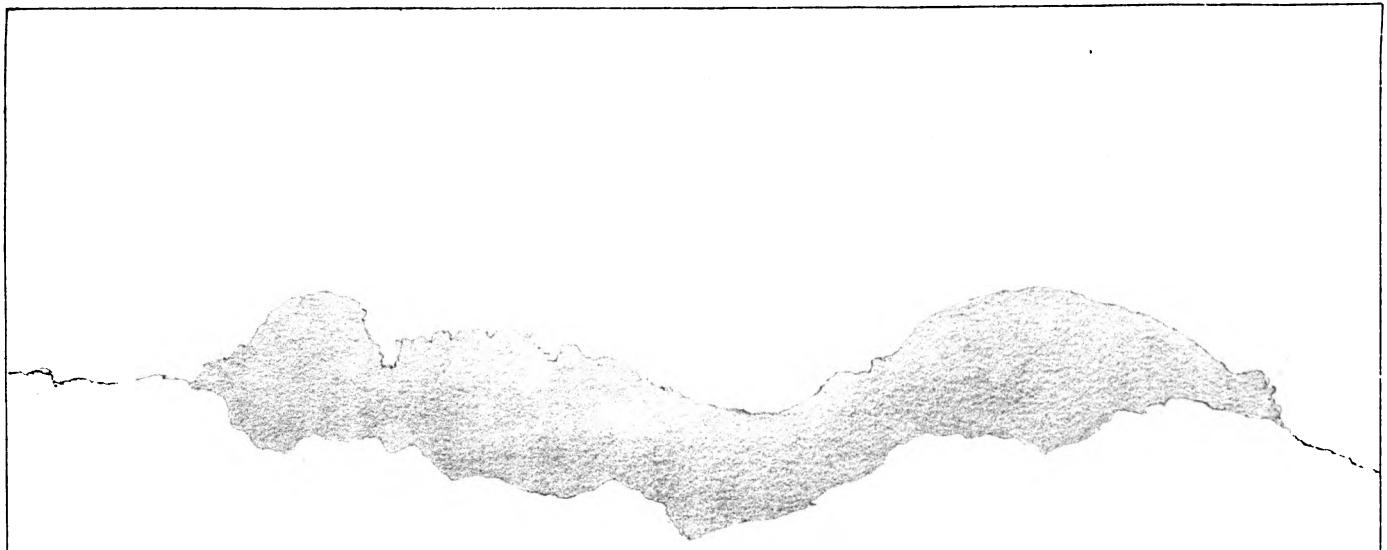

TOP OF SUILVEN FROM N.

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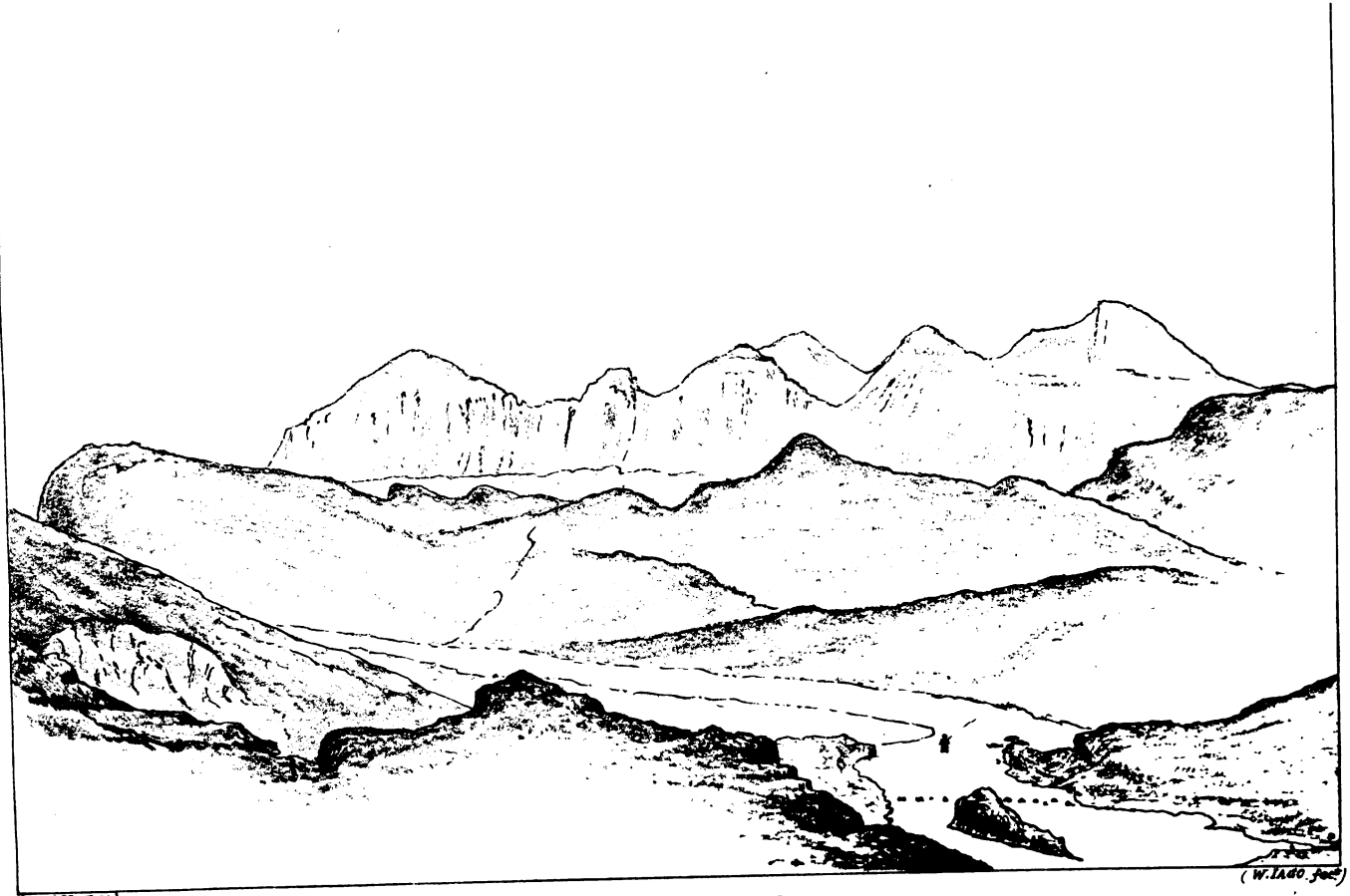

(M.F.H. delt.) (W. Lado. fec.)

Western Escarpment of Quinaig.

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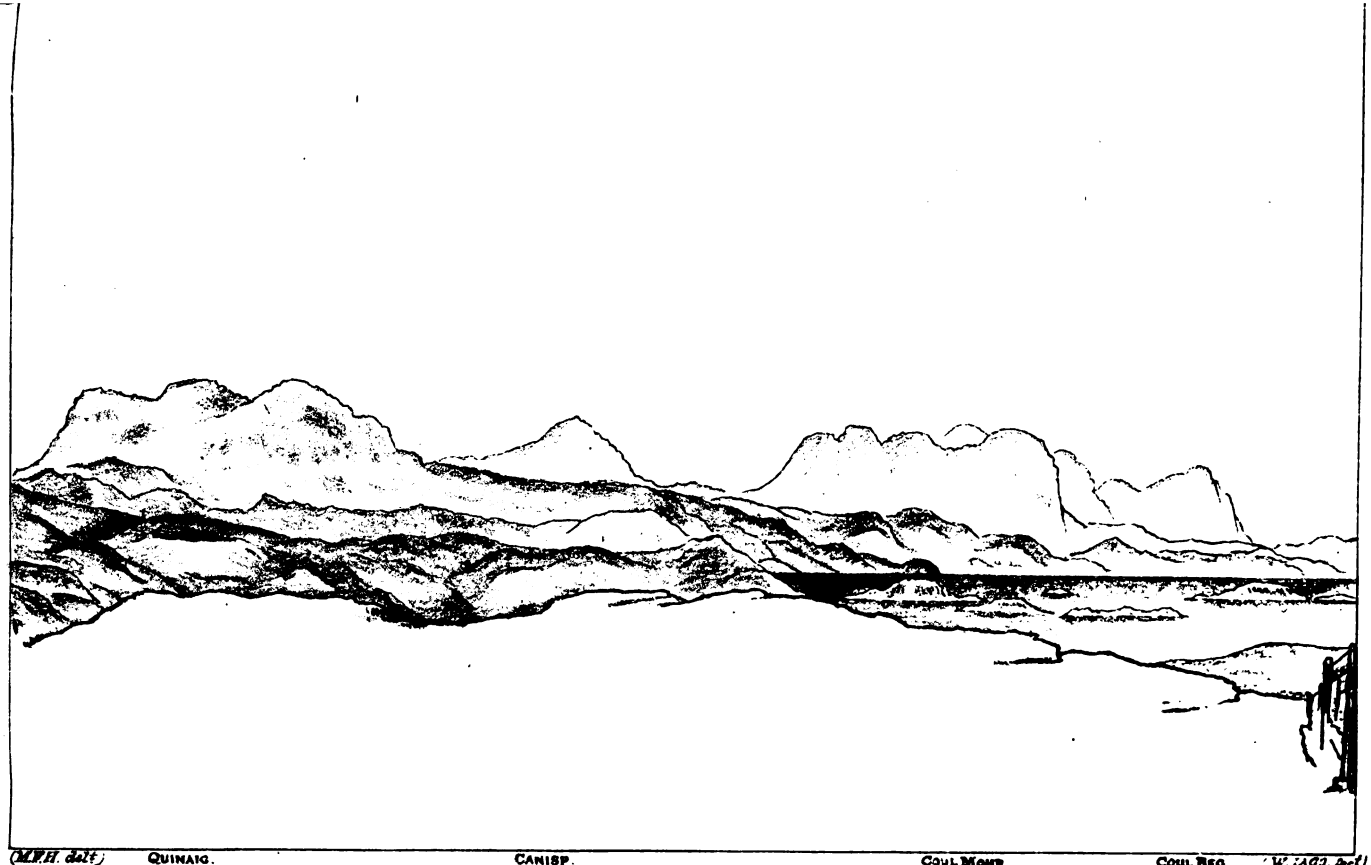

Broken Escarpment of the Conglomerate, seen in Flank. — from Handa.

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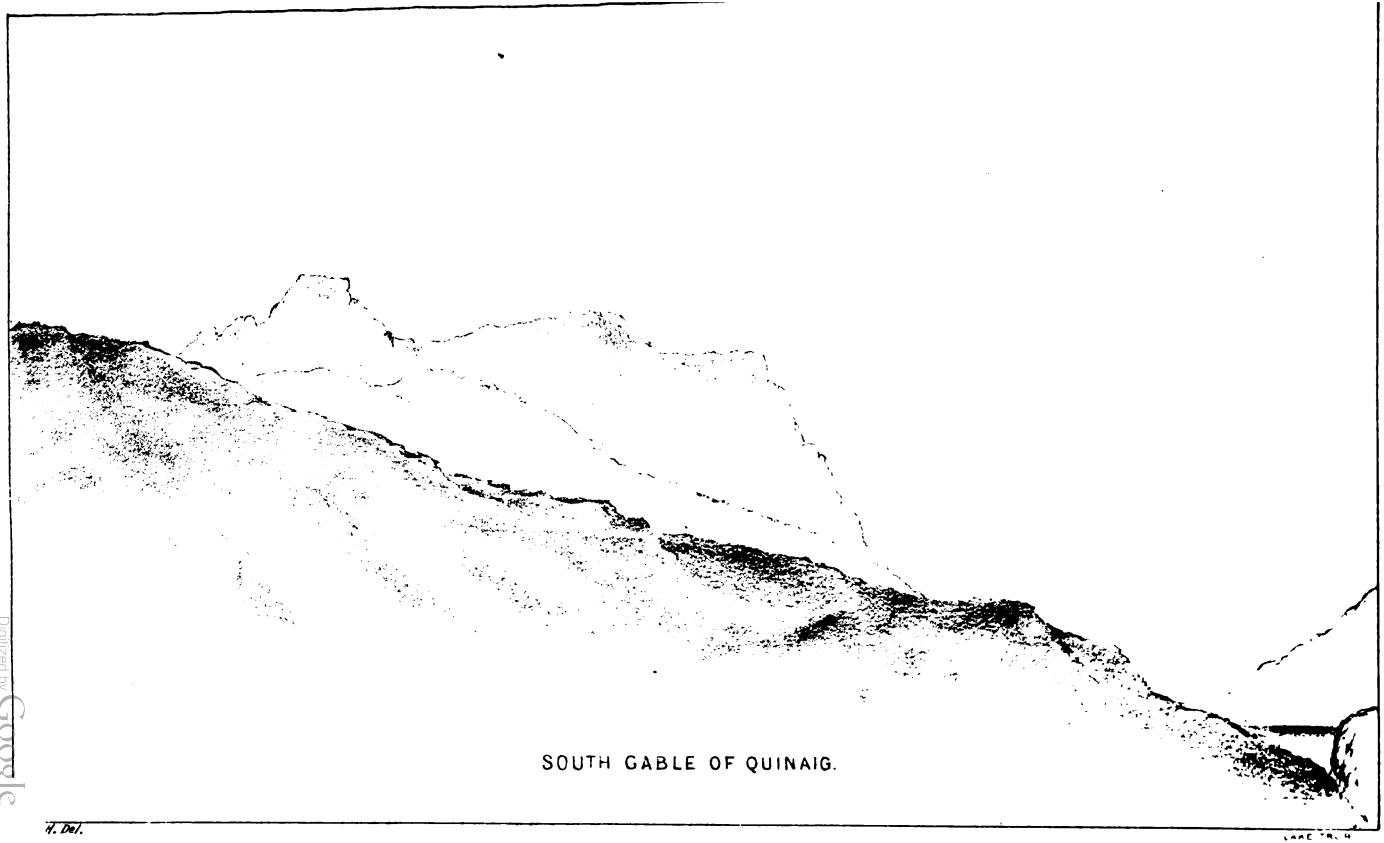

SOUTH GABLE OF QUINAIG.

H. Del.

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away its slopes, so that it is in that last stage of ruin, which exposes the increased surfaces of a ragged edge, disintegration is here advancing with abnormally rapid strides. Parts of the rock, as stated, are being blown away in sandy dust.

The contemplation of such a spectacle of rapid disintegration as is here presented, would lead one to conclude that the time requisite for cutting out the trenches which lie between,—or, to be precise, which *actually form* the Torridon hills,—need not have been by any means vast.

When the features of the formation as a whole, however, and the circumstances which obtain at this one spot, are considered;—in a word when the *mode* of sculpturing here and elsewhere is investigated, it will be found that the spectacle at Stack Polly is altogether an exceptional, and a very misleading one.

It was stated that the beds of this rock were divided by a "rude prismatic structure:" this is a marked feature of the formation. It is the falling together into one line of many faces of these prisms, which gives rise to that rectilinirity of the cliff-faces which is seen to prevail. Other faces falling together, produce more or less continuous transverse rents. Into these the peeling of disintegration throws the sand-grains which fall from the opposed surfaces; and out of these the wind, striking the flatly-extended line of cliff, sweeps them,—as it insinuates itself with concentrated force into the crevasses, like the separated fingers of an opened hand.

As the prismatoidal rents pass down through many beds, the rock is gradually cut up into a system of isolated rugged pillars. Striking instances of these are seen in Teallich, Coul Mohr, and most markedly in the "Old Man" of the Rhu Storr.

At Stack Polly the sides of the pillars have peeled off; until only needles, separated from one another by rents, widened into wind-funnels, now remain.

The disintegration of a Conglomerate rock is accomplished by the loosening asunder of its component granules, through the soak of water,—very much more than through the per-oxidating effect of the air. The rounded and agglutinated granules had come through a worse trial as regards the attacks of the latter agent, when they rolled as a loose shingle, than they had to do when packed together as a mutually cohering mass.

The amount of action of solvent water upon a granular, that is an interstitially-porous mass, is in the direct ratio of its penetration. In calm, that penetration is simply due to capillarity; under wind-pressure it becomes wedge-action. A sandstone wall may make a dry house if

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the rain is merely streaming over it, in calm:—that rain streams down the innerside of the wall when blown through in a storm; and that the more, the heavier the gale.

Say that the penetration is an inch, with a wind-pressure of 10 pounds on the square foot, on the wall-precipice of Quinaig:—what is the pressure, and what is the amount of this loosening penetration, at the top of one of the wind-funnels on Stack Polly's ridge?

One such funnel the writer ascended,—situated on its N.W. face. It was about five hundred and fifty feet in height; and the extent of cliff-front, which in a northwest wind would direct the blast into and up this funnel, was about six hundred feet, at the base. The whole of this concentrated force of action, (which,—making a large allowance for a great deal being thrown out of the funnel by its elasticity,—must yet have approached the point of liquifaction of the air,) was thrown upon the narrow neck which connects the summit with the ridge. What has it done there? Doubtless it formed that neck originally; but lately it may be said to have cut the neck in two. The exact date at which the Cairn on the summit was erected, we could not ascertain; but that Cairn, now overthrown by the wind, has not been reached for seven years. And after all, the *one step* which was blown away, grain by grain, and the want of which renders the summit inaccessible, was little over a cubic-foot in bulk.

While a cubic-foot, in say twenty years, seems a most rapid destruction, it has to be borne in mind, that elevated ridges of hills, which catch every wind, and which are so constantly steeped in mist, or enveloped in condensing-cloud, are altogether differently circumstanced from the main bulk of rock which lies in comparatively sheltered trenches; and such spectacles of destruction as are to be seen upon Stack Polly, however instructive in their way, are altogether misleading, in a consideration of the time necessary for the removal *of the general mass* of a formation.

It indubitably would be equally aside of sound arugment, to maintain that those portions of this formation which have been removed, were the softer; and that the remaining fragments were self-evidently more enduring, because harder. The nature of the even-bedding, and the unvarying texture of the many layers of the rock, in themselves form an ample contradiction to such a view.

The occurrence of east and west faults, either in the centres, or along the lines of the trenches, entitle us on the other-hand to hold, that the already-considered process of continuous widening of a crack, and sweeping out of the resultant waste, might have been the first step in the process of this trench-formation. That the succeeding steps

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may have consisted in the rush of waters through the wall-sided chasm so formed;—in the establishment of a drainage system,—and in the continuous downward wash, and slip and slide, and flood-scour, which constitute the various steps, by means of which a rain-drop is the primal operator in the forming of a valley. And thus we might argue that it is through their *intermedicity between these faults* alone, that the the remaining fragments stand. But while holding that the ordinary processes of valley-formation, operating along lines of weakness, are sufficient to explain the isolated position of these residual masses, the preponderance of probability indicates another mode of channeling of the gaps which occur in the continuity of the formation. Indeed the level of the Hebridian pediment at east and west, is too perfect to lead us to believe that the scour of running water had much to do with the abstraction of the material which originally linked hill to hill.

The facies of those lines of rock-wall is altogether that of sea-cut cliff; so much so that we can scarce entertain any other explanation, than that an angry ocean had for long ages lashed in fury against their sides; and formed the basement-line out of, and over which they rose, sheer and inaccessible.

And in this consideration of the mode of waste of this formation, we cannot but pause as the spectacle which these isolated rock-islands must have presented, images itself forth upon the mental eye. No such spectacle does Britain anywhere now present:—much do we question if such is to be seen in the wide-world.

It is worth the seeing, and there is but one way of seeing it;—clearly, as if by open vision, has the writer often seen it;—he could even *picture it;* but it is indescribable. The Faröes shoot up their trappean cliffs from deep lanes of water, with a precipitancy so great as almost to close the land over-head, and eclipse the Zenith; but even their stepped rocks would appear altogether tame when compared with those of mountains standing isolated in the sea. St. Kilda is of the type: sprinkle the Ocean *with a group of such,*—gigantic in their bulk,—and then consider the picture.

Whether the land was dissevered by scouring rivers, or beating waves, matters little in a consideration of the amount of force, and of the time requisite for the work:—both are but modifications or outcomes of the same primal power. Deltas might establish the operation of one; sand-banks and shoals of the other; but the clean sweep of the after ice, has left neither:—so that calculations which we might have based upon either, are not within our reach.

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We may cite the extreme apparent hardness of certain portions of the rock, as an offset against the loose grains of Stack Polly. Or point to the rolling boulders on the shore of Handa; the smooth external polish of which, equalling that of the surfaces of the imbedded nodules themselves, points to a durability which has, through long ages suffered no diminution. We simply find ourselves, with the data within our reach, unable to master the problem of the time, or the force called for to accomplish this great disrupting work. Fortunately, it has been approached from another starting-point; and a sister science has held out a helping hand. We have all agreed to go to the Sun as, of material objects, the one from which all force, as concerns our Globe, emanates.

Dr. Haughton, in a very remarkable paper lately published, (from which I extract, briefly, results only) lays down, that—The heat *received* by the Earth per annum, would melt an average thickness of ice over its whole surface of 80 feet. The mean annual *radiation* of heat *from the Earth*, is equivalent to melt a coating of ice 28·5 feet in thickness; so that we have 51·5 feet of ice representing heat, *not accounted for as heat*, (for the mean temperature of the Earth's surface is not being increased year by year).

This large balance of heat is expended,—

1st. By being converted into geological work, done by rainfall and rivers.

2nd. It is converted into chemical and vital work, done by vegetables and animals.

The mechanical or geological work done in crushing to fine powder a cubic foot of rock, was estimated from data taken from the stamps of Polberro Tin Mine. Each stamp weighs 600 lbs, and is lifted and falls through 9 inches, 45 times in one minute. Each stamp crushes 28 cwt. of tin-stuff in 24 hours. Hence the work done in crushing one cubic foot of rock is equal to 713·5 foot-tons.

The geological work done by rain and rivers, takes 3,090 years to crush and carry off to the sea, one cubic foot of surface rock. (One foot in depth evidently meant).

So far Haughton. Let us now apply this: taking a portion of the district under review, to do so.

Suilven stands in nearly the centre of a great denudcd tract; it remains as a voucher for the ruin and removal of all that once connected it with Quinaig on the north, and Coul Mohr on the south. It was hewn out of a great flat sheet of the Conglomerate, in much the same way that there is reason to believe the Sphynx was hewn out of an isolated block of stone, in the Desert: from both, the sides were cut

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away, and the residual block fashioned very much each in its present image. From Dr. Haughton's data, we can get at the amount of force necessary, and the time necessary to cut out Suilven; and then we can calculate the cost.

The depth of the formation is got at by drawing from the height of Quinaig, say 2650 feet, an air-line to the top of Coul Mohr, say 2,700; and abstracting the height of the Hebridian foot of Suilven, say 650 feet: leaving 2,000 feet of thickness, cut away. This, multiplied by 3,090 years for each foot, gives six million one hundred and eighty thousand years, for the time requisite for the full *geologic-work power* of the earth's share of sun-force to accomplish it in. That is for *the chiseling out*, but not *the building up* of the hill.

In laying our rule across the country to ascertain the amount of work for calculating the cost, we have to apply it, first as regards the *width* of the rock which had to be removed, in order that the tombstone might stand well isolated; and we find, that from the cliff-face of Quinaig, to the equally well-cleared off frontlet of Coul Mohr, is eight miles, (42,440 feet); that is the narrowest part. Next, for the *length* As no other tombstone has been left to obscure the view, either in front or rear, the Conglomerates are clean gone, from the point where they dip under Canisp, to where a fault, apparently, has hitched them down out of the way, at Stoir. This is eleven miles, (58,080 feet).

42,440 × 58,080 × 2,000 = 4,889.830,400,000 cubic-feet,—or 181,105,829,629 cubic yards of Torridon, to be shunted out of the way. And this had to be done, not by dynamite, tossing a thousand or two of tons aside at once, but grain by grain; through the operation of a process which *used up* precisely the same amount of sun-energy as is consumed by the force employed in crushing by a stamp-mill.

What is the labour-value of this work?

In India and Australia, where the time-value of attendance on stamping mills is the lowest; and where experience has adapted the force of falling water in the most perfect and the most thrifty manner, the lowest cost of crushing a ton of rock (after it was quarried) is three shillings and seven-pence.

Each cubic-yard of the Torridon rock may be taken as weighing two tons. So the *money power* necessary for cutting out this one hill is £63,386,690,587. This may be regarded as the value of Suilven,—*scenically:* and it imparts some faint idea of the immensity of the forces of nature!

The *second element* of the diverse scenery is afforded by an almost

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equally dissevered range which stands immediately behind and eastward of the sentinel-hills of Coigach.

The hills of this more easterly range, from the purity of their colour, and from the brilliancy of the light reflected from their peaks after rain, were declared by Pennant to consist of marble; but the material is quartzite.

Occasionally they stand isolated, blocking up at short space behind, the interspaces of the Torridon range; generally, however, the rock which composes them forms merely a cap to some portion of these elder-born hills.

We have already seen that when the old Hibridian land was depressed, and when the gravels and grits of the Torridon sandstones were deposited upon it, the eastern range of its hills still remained above water. But it was not so when the land again sank.

There is no peak, not even the loftiest of the range, which was not now overflowed.*

The shore-line of the new sea was not far distant from that of the older, though here again denudation does not permit of its being laid down with any pretension to accuracy. Two facts are patent,—the waters in which the sediments which were to form the new land were laid down, lay nearly altogether to the *eastward* of the previous; and these waters, with the coarse gravels and sand which settled in them, overlapped to an extent of over a mile westward, the shore-line of the Conglomerates.

The fact of, and the manner of this overlapping, renders it easy to fix the period when the great trenches of these conglomerates were channeled.

First, as to the manner of the overlapping. It is, at least for a long stretch in the northern portions of the junction,—in fact throughout all the Sutherland and Cromarty portion of it,—easily seen that the two formations are not conformable. The contrast of their colours makes this readily observable. The easterly dip of the Conglomerate averages 5°;—that of the upper formation, which is also easterly, averages 7°; while in its dip it swings more round to the south.

It is evident that there had been some amount of denudation of the outcrop of the Conglomerates, before the covering beds were laid down; it is also evident that now the great *general depression* of the land, or at least the *localisation of the sedimentation* was to the east; this is proved by the upward succession and continuance of these beds in that direction; while the higher dip of these to the east is strong ground for holding that the sinking land subsided to the *greatest*

* I cannot speak as to the Maiden, never having ascended it.

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vertical extent to the westward, but was, upon re-elevation, restored to much the same horizontal level it had stood at when the table-land of the old gneiss was formed.*

The overlapping of the Conglomerates had to be upon their upper beds—but that overlap must perforce *have shown itself upon their lower beds also, if these had been trenched by any local denudation, previous to the sedimentation of the newer rocks.*

This overlap is seen stretching westward over the slightly-denuded outcrop-beds of eastern Quinaig; it sweeps up the hill to an altitude of about 2300 feet, and to within a fourth of a mile of the peak; and its altitude upon an opposite peak might entitle the assumption that, had it not been since denuded off, it would have appeared overlying the summit itself of the hill. The opposing peak of Torridon Sandstone upon which it appears, is the more northerly and more elevated of the twin summits of Coul Mohr. It is an outlying patch of quartzite which thus appears; but the main bulk of the rock creeps over the eastern bosom of the hill, into close proximity with the outlier.

Thus then we see that the ocean of this new rock,—the snowy Quartzite,—had extended westward, at least to the line of the summits of Quinaig and Coul Mohr, and had there welled upward to a present altitude of over 2600 feet.

Had then the great trench-valleys which lie between the Torridon hills—as the two between Quinaig and Coul Mohr—existed *before* or *when* the land was depressed, the waters would have rushed into these gorges or channels of the island-hills, and *deposited in them* the lowest beds of the quartzite.

But no particle of the quartzite has *there* been found;—it extends westward only on the hill tops;—it is there that the lowest, most pebbly beds are found. The denudation of the Torridon was quite trifling before the deposition of the quartzite. That quartzite therefore was laid over it while the lower rock was still a continuous belt; and that enormous transverse scooping of the Torridon, which resulted in the formation of those monolithic hills,—which according to

* There probably was a fault some miles to the west,—the Lewisian Land being left, throughout the deposition of the quartzite, above water. Was it the fault which cuts-off Handa? It would be an easy explanation of the reversed dip of the Torridon rock—usually S.E. in Sutherland, N.W. in Torridon—to hold, than an axis of elevation ran up the country along the line of reversal. It would be most satisfactory if this could be found; unfortunately, although that line is in many places admirably exposed for investigation, there is evidence *along it* of neither folding, crushing, nor of fault. Of course, in accordance with the requirements and dogmas of fire-side geology, there *must be* one or other.

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Macculloch, "have *no connection* with anything around them,"—but look "as if they had tumbled out of the clouds,"—took place in some comparatively recent time. Certainly more recent than the faults which have cut through both formations;—a time indeed when Conglomerate and Quartzite, and still more recent rocks, were trenched together.

So that here as elsewhere, "Nature's first step—like the patriarch of old—had been to bury her dead out of her sight. She hastens to conceal and hide the ruins she has made. Then after a time,—often a long, long time,—she again exhumes them, bids them as it were live anew, rise up and tell their story."

In the marked contrast afforded by the dead-white quartzite capping the purple grits, and in the full exposure of that contrast in the clean-cut transverse trenches, we have arrived at a *second* explanation of the striking scenery of the west.

For *the third*, neither eye nor foot has to stretch far; we have but to step a mile or so further inland,—passing over the debatable ground, the shore-line of the ancient Torridon Sea,—and note the strange contrasts which present themselves, where the snowy rock sweeps over and inwrapps the higher summits of the sombre Hebridian Hills.

There is here far from the same tranquil reposing of the one rock upon the other, that we found to obtain where it overlaid the Torridon. There was not here as there, anything like a gently-sloping platform for the sedimenting sand-grains to rest upon. The bottom was one of the most uneven imaginable; for the range of hills had, during two successive epochs, stood bared to the agencies of waste, and had been cut-up into sharp-featured, and, in some cases, into isolated peaks.

From the vast quantity of debris which has rolled down all the slopes of those hills which are capped by the quartzite, it is not easy to find spots where, either on the slopes or at the lower parts of the hill, the foundation-beds are disclosed; and so co-ordination of the several beds is well nigh impossible. Nor is it easy to pronounce where the faulting has let down a huge junk into a totally anomalous position. But from their great thickness in some localities along the strike, and thinness at others, there is every reason here to believe that the sands may have been in some spots deposited in pre-existent troughs

The great hill of Arkle seems to have been cut out of such a sand-filled trough; if not so, the space between Fionaven and Stack must have been faulted down, before the more recent denudation carved out the hill.

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Ascending Foinaven, which flanks it on the north, we do not, at a point immediately opposite to Arkle, reach the quartzite until we attain the height of about 2,500 feet. Upon Stack, which opposes it upon the south, we find the lowest pebbly beds of the formation at the height of 2,350 feet; while in Arkle there are beds (but whether the pebbly beds, cannot be ascertained) as low as 800 feet, resting upon a low hill of hornblendic gneiss. From off the southern portion of this low hill, they have been denuded, leaving a flat terrace, which slopes gently to the east, but precipitously to the south. This terrace when viewed from the swellings above the head of Loch Stack, has a most singular appearance; forcibly illustrating both ancient and recent denudation.

This central district of the range is typical as exemplifying outlier cappings of the quartzite.

Its more northerly stretch however, illustrates what may be regarded as the appearance normal to a hill-range, which is overlapped by a new formation. Northward of Foinaven, the linked chain of hornblendic hills is taken up by Cranstacach, then by Spionnaidh, while lower elevations stretch onward, to end the land in Kean-na-Bin.

Of these hills, the first-named are overlaid by a long sweep of quartzite, in a range of vertical precipices of over 100 feet in height,—the over-lying beds drooping gently eastward till they pass under the waters of Loch Erribol. From off the green hornblendic rock of the more northern, the quartzite has been denuded.

The continuous eastward slope of the sterile quartz formation has conferred the name of *Hill of Desolation* upon the middle height. No spot of earth could surpass it in sterility and deadness, it is typical of inertness and absence of motion. "All this barrenness, sterility, utter absence of life, is the result of the indestructibility of the quartz. It is dead, because the ordinary powers of nature cannot act upon it. It wants the higher organic life, because it endures too long as an inert inorganic mass."

Regarded from the west, again, as we pass down the lower Strath of Dionard, the appearance is altogether different; for the towering green rock, capped by the long stretch of white, is the very embodyment of a great ocean-billow, sweeping westward with its curling crest of foam. In Meal Maonich and Meall Meddin, the billow is heaving upwards, but the curling cap is gone.

The main bulk of the quartzite,—and this belongs to the highest member of the system,—lies in the vicinity of Ben More and Bræbag.

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There is much greater thickness here. The unevenness of the bottom partly accounts for this; for the Hebridian rock had here been denuded down to an altitude of about 1,500 feet; only one small point indeed of such an altitude,—which is seen west of the Dhu-loch-More—appearing. But there is also here a much greater actual thickness of the formation.

The hills of this upper series bulk well as back grounds, from their tone of colour exalting the effect of those already noticed; but they cannot, apart from their gashed and riven cliffs, be said to be possessed of either grandeur or beauty. "Their cold, spectre-like aspect, when remote, is almost warm and living, compared to the bare icy sterility that reigns amid their glens and corries. The rocks smoothed and polished by ice-action, shine with dazzling whiteness. No flower or tree, scarce the hardiest lichen can find root or soil in crack or crevice. Rare patches of black moss—blacker from the white basin in which they rest,—a few detached stones, broken by the winter storms from the higher pinnacles, alone diversify the surface. There could scarce have been less life there when the snow nevé filled the upper corries, and the ice-river flowed down the Glens."

Still, here, just where something is wanting to break in upon the sameness of their interminable bands of white stone, that something appears. An interstitial band of grey limestone finds a most fitting place; here, presenting a craggy ivy-clad frontlet, there a stretch of verdant sward; here a chain of pellucid lakelets, and there again just that sufficient glimpse of the greenery of cultivation, which introduces the element of human sympathy into the scene. And here, yet again, to relieve the eye both from sameness of colouration and tameness of outline, there start up bosses of igneous-rock, and cleft face of fault,—intruded sheet, and great lime-swallow; churning the land into a tossed heap of fragments, so that this is the accepted summer-haunt of the querulous, the much affected battle-ground of the quarrelsome.

Had we to assign special forms to the hills of each of the foregoing formations, we would connect the conoid form with those of the Hebridian rock; the serrated ridge with aiguille peak would be assigned to the Torridon, and the long cliff-face escarpment to the Quartzite.

The forms assumed by the latter formation, however, depend much upon the underlying rock. When this consists of the Torridon sandstones, and the *lower* quartzite is under consideration, the definition of long cliff-face escarpment applies; because, from a certain similarity

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both in the mode and size of the jointing of the two, and from the *underlying* rock giving way most, the amount of debris which results from the waste of each is much the same; and this debris having been equally thoroughly scoured off, clean-cleft cliff-faces, and hill-slopes but thinly covered with fragments, generally appear.

But, with the *upper* quartzite, and the uneven bottom of the old gneiss, it is very different; the fractures of this upper-bed are very much more numerous and open; in many places the rock, nearly pure silica as it is, appears rotten, and is highly shattered and fragmentary. There is a northerly projecting spur of Foinaven, which has a sky-line like the backbone of a skeleton horse; while the south-westerly shoulder and slope of Bræbag is a mere heap of ruins.

There is something altogether extraordinary at first sight in the amount of looseness of the clean-cleft blocks which lie in enormous profusion over this rounded, but exceedingly steep slope. One might almost suppose that they had been sparsely imbedded in a calcareous cement, which, having been dissolved away, had let them light upon each other, in all positions of loose arrangement. Each one seems to be upon the move, so that the descent over them calls for a most attentive eye and an ever-agile ankle.

The extreme looseness of the stones upon hill slopes had often puzzled the writer. Upon hill tops, the constant drench and drain of water cleans out and sweeps off all small particles and binding clay; upon most rock-runs and "scridans," the surface-stones at least, have been chance-caught, as each was experimenting for itself upon the angle of rest. These are evident; but the cause of the looseness of stones upon *moderate* slopes, and in such positions as that on Bræbag, the writer only attained to the knowledge of, very recently.

Mentally he saw it, or saw through it, a few years ago on the cliff-foot of Cranstacach; visually he *saw it operating* a year or two after, upon Am Binnian, in Perthshire.

Driving snow and sleet is forced, first from this side then from that, into every crevice of the loose-lying blocks. As these blocks have the warmth of the earth, a certain amount of the snow is melted. The water trickles into the crevices, and is held by capillary attraction in the narrow chinks between the stones, and in the close neighbourhood thereof. At night this water freezes;—expansion, irresistable expansion takes place; and every stone, at least of the superficial layer, is lifted upwards; settling, when the thaw ensues, gently down into an altogether-loosened poise.

So, precisely as the bird, by thrusting its bill through them,—or the dandy in "sprushing up his hair,"—so does old Mother-Earth

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yearly plume herself,—shaking her stone-feathers loose. The only difference being that she chooses the winter-time to do it in, and the dead of night.

A strange feature of the scenery of this sterile formation remains to be noticed.

The closeness of the rents and fissures, especially of the superior member, has been adverted to; it was specially instanced in the loose blocks of Bræbag, and the stone-runs of Foinaven. But disintegration goes no further; that ultimate loosening of the cohesion bonds of the rock, which would result in shifting sands, is nowhere seen; and thus, grim and ghastly, like the dead bones of an older world, it protrudes above the surface.

It is the destiny, and it is the duty impressed upon every particle of matter on this globe zealously to prepare for a new service as soon as each earlier commission is performed; and, measured in the great cycle of revolving time, it is not long that any particle lingers in any one stay,—in the performance of any one function,—or as the special property of any one fabric;—for it is urgently called for by others. The wondrous machinery of nature is fashioned of materials, which no one of its parts can ever claim as peculiarly or abidingly its own. The attrited nodules, for example, which went to form the eldest-born conglomerates,—fall out of place, ever to rise higher and higher, performing, with constantly diminished bulk, the self-same function, to younger and still younger rock.

Similarly rounded and worn *pebbles* of this quartzite formation have been recognized by Bonney in the conglomerates of Arran, and in the Bunter pebble-beds of Staffordshire; and the writer has fancied that they formed a part of the conglomerate of Heclabir in Orkney. But the *sandgrains themselves* are not set free,—as usually obtains in a sand-grained rock.

That this is, and was such a rock is proved beyond doubt by the myriad worm-holes which pervade it. These may be seen in ascending Bræbag from Lynn, throughout the whole thickness of the last heave of the mountain,—over 1,500 feet.

At right-angles to, and through each bed, of less than two feet in thickness, do these plugged sand-pipes pass; sometimes proportionally as close as are the holes in a draw-plate. Silent witnesses,—beyond number numberless,—to the fact that the whole great hill was in its successive layers once tide-washed by the waters; and that its shifting grains then gave place, and yielded a ready passage to such a teeming of existences as, in the life-history of our globe, has never been surpassed.

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But these sand-grains yield no longer. They are now united by the dovetailing of partial inter-penetration, and by the cincture of silicious and ferruginous cements; and that so closely, that the rain-drop finds no chink for its wedge-edge, and nothing which it is potent to sap out.

Neither have the *saline* waters prevailed, in effecting more.

"As the sands of the sea-shore for multitude." Of *what* sea-shore? Truly he would be far-travelled who could point to the *sea-shore* whereon there were no sands. No tropic,—no clime,—no country; unless it were an ice-fringed verge. Nature,—conservative in general principle, willing to submit only to gradual and slow change,—knows well her best breakwater, and spreads out her gently-sloping sandbanks to fringe the land, and cheat the billows of their might by that gentle yielding, or appearance of yielding, which turneth away wrath.

As for *country*, so for *formation*; silica prevails throughout. Our own country teaches us this, not less well than any. The Hebridian gneiss of the Long Island is fringed on the west from end to end with great tracts of loose sand-grains At Sandwood and at Kearvaig, the Torridons show the same. The disintegrating quartz-bands of the Upper Gneiss have filled up grand harbours, and *made* the cockle-growing Kyles of Tongue and of Duirness; great cliffs of the Old Red lie grovelling in the Bay of Thurso; so also of Coal-measure shores; and the recent formation at Gruinard, whatever it be, has, as it blows about, given the name of *Sand* to the locality.

But it is not so of *this* formation. It is anomalous in its lethargy. The bond which unites its particles is indissoluble; and the sheeted slopes of Spinnu, plunge, unswaddled by any such fringe, into the deep dark waters of Loch Erribol;—for the rock is, in its very nature, *iron-bound*. So is it also that it endures, the highest land in the county; but, in *even-bedded and shapeless forms*,—for it is unhewn; and, with the chisels at present at the disposal of Nature, it is unhewable.

The effect of lime as a fertiliser is nowhere so strikingly apparent as where it occurs in but small amount; or in isolated spots among rocks which are destitute of any mineral containing it. In this district of Sutherland, highly siliceous rocks so prevail, that its effect as such, may be said to be exalted into its acting as a *populator*. Such has for long been its enduring, or rather it may be said, its *still-abiding* function,—from Erribol to Loch Kishorn. The clustered hamlets at Innisnadamph, Elphin, and Knockan, give evidence of local amplifications; while intermediately-disposed shepherds' houses form with these the connecting links of a far-extending belt of greenery.

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Beyond or aside of this, the limestone has little effect upon the scenery; it has indeed little of its own that is visible.

Of that which is invisible, except to the mind's eye, it has much; and a wondrous scenery it must be,—judging from the glimpses of it which we can obtain.

The traveller who passes along the road which, southward of Knockan, skirts the foot of the great limestone cliff, must, after wet weather, be delighted by the numerous gushing springs which discharge their sparkling waters, apparently from forth of the solid rock. These, however, from their small size, can hardly prepare him for the spectacle of a rapid-running brook, issuing from beneath his very feet, to whose sources and beginnings the perseverance even of a Livingstone could never attain. On this side of the road it *was not*;—you rest upon the solid rock, which towers overhead. On that,—there flows the brook, ready formed; rushing with such ample and such swift flow, that you speculate whether even the agile trout could stem its waters, and shoot into those dark abysses to learn the secrets of their mysterious vaults.

There can be but little doubt that the faulting which occurs in connection with the limestone throughout its whole range, suffices to explain its hidden streams, its "sinks," and "swallows." The surface-waters,—finding their way into rents, which primarily were no more than breaches of continuity,—soon would dissolve the walls on either side, and form free channels of escape.

To such an extent has this taken place eastward of Stronchrubie that the whole formation is in a carious condition. Loch Maolock Corry catches the drainage of an extended district, but the point of the escape of its waters is for the most part undiscernable. That they do escape, and that in no stinted flow, is vouched for by the "Boiling-spring" which gushes from the south side of Ben na-creisag: and, on the north side of the loch the secret is to a small extent declared, and a brief glimpse of their hidden workings is vouchsafed.

For short space the waters of a limpid stream quietly glide between softly-swarded banks, suddenly to be precipitated into the abysses of a gaping chasm. The horrors of that yawning gulf seem only the more horrible from the elastic softness of the green mantle which creeps to the very verge of its treacherous lips.

Short shrift to him beneath whose incautious feet that verge crumbles; jagged projection, and alternately protruding buttress, would unjoint him piecemeal, as he shot from the bright reflection of limestone effulgence, through that grey-gloom of middle distance, to plunge into a blackness of darkness, which looks solid in those far-off depths.

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But it is far from solid. The thunder of the ever-falling waters sends up a hollow boom which tells of oft-repeated plunges; and the tortured and disjointed surface, gaping ever and anon with inosculating rent, and trenches cinctured with treacherous sward, speak to the rottenness of the land. The firmest foot may well tremble; the stalwart stride, brings no safety to its possessor, for *it* will be the first to break the crust. Tread gently here, you are over a grave, and the firmament is "waning awa."

Göthe must have been in Scotland! He must have looked over that horrent verge; he must have imagined *his* body taking that crashing plunge,—or he never could have written "Abandon hope,—&c."

Could the passage be explored? for the waters come to daylight again, less than a mile to the north. We should like to try,—armed with a rope, a pair of miner's clamps, a bag of compressed air, and a pocket-full of condensed sunshine, in the form of magnesium wire. And we might, were it not for the treachery that is around, above, on either side, and below. What hidden horrors there must be in that "middle passage," what scenes of gloomy grandeur, domes of blackness, and pitfalls of pitchy perdition!

Why go to the Mammoth Cave when we have a place like this in Scotland? There surely might be satiety with a tunnel a mile long! Could a pigeon be trained to prospect,—they are curious after holes! It were vain,—for the roof doubtless dips into the waters, with repeated flexure, and bars the way:—"*there is a path which no fowl knoweth, and the vulture's eye hath not seen.*"

The waters of this burrowing stream steal to light in the most covert manner, muddling themselves up with those of surface rills which have accommodated themselves to the "caved-in" trench of the subterranian channel. But there is just such-another darkness-loving rivulet, in the north of the county, which debouches in no such stealthy fashion; but which, from its raising its head just at the ocean's verge, as if it desired to render its tribute to the main with no insidious gliding, has produced a scene, to use Macculloch's words "alike extraordinary and impressive."

This is the cave of Smoo.

It is significant of its wonders that even the graphic writer above quoted has failed utterly in describing it; and, from the excuse which he offers, he seemed to have been conscious of his failure.

But even a greater than Macculloch would seem to have considered it beyond his powers. That he who wrote the wondrous descriptions of Coruisk and Staffa, should feel himself unable fittingly to grapple with Smoo is most significant; and we believe that by most who

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thoroughly, and *in fitting circumstances* explore it, it will be regarded as the most wondrous scene ever beheld by them.

But the spectacle at Smoo is dependent to a very unusual degree upon circumstances ;—the circumstances here called for being an over-flowing volume of water. We do not suppose that even Niagara would be much *as a cliff*, if its waters were dried up ; and certainly Smoo is reft of all its eerieness and gloom, and of much of its glamour also, when visited in drought.

It may have been considered that in our remarks on the scenery of Sutherland, we have made use too much of the penetrative eye of the geologist, in detailing *subterranean* pictures ; but *here* we must descend to a still lower depth,—nearer yet a step to the central core,—and consider much that is *subaqueous*. Little that is subaerial has Smoo to show ; but that little has a charm which contrasts most forcibly with, and enhances by a contrast of altogether-unrivalled abruptness, the pandemonial blackness of its other scenery.

In ancient days a rivulet has thrown its waters in spray from off the verge of a straight-lined limestone cliff; and through long ages has eaten back, at right angles to that verge,a wall-sided trench ; this has an inward depth of over four hundred yards, and an altitude of well-nigh a hundred feet.

Those who wish to know the colour of pure Atlantic water may learn it, in the flooring of that chasm. Such cannot be seen in the English channel, or in the Pentland Firth ; for these are but the drains of the German Ocean,—the mud-polluted cesspool-sink of all Europe. It may be seen still purer to the west of Harris ; but that four hundred yards by fifty, is so glorious in its pellucid green, that it sparkles gem-like,—even in similitude of a huge aquamarine laid down upon the land.

The southern land-floored end of this great trench is a *cul de sac*, half-domed and roofed by a thin shelf of rock. The light which slumbers within that dome, once seen, is *felt*. The light—what they have of it—of all caves is fine ; that of this is surpassingly lovely. Poets would call it a *chastened* light. If by that, is meant that it resembles a character which, through the buffetings and disappointments of the world, shines with a softened sweetness, we partly understand the application ; and it would here be a fitting one. For chemists,—monsters, who are always insisting that "lovely visions are to yield their place to cold material laws"*—tell us that while the light which

* Beg pardon, Sir; chemists and other naturalists only maintain that beauty will be appreciated all the more if its *causes* are understood. P.D.

Right, my boy;—and so the *primal source* of these "causes" more nearly approached.

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is reflected from a smooth metallic surface shows but little of the colour special to the metal, from its being overpowered by the glare and glitter of polished reflection, the same light when reflected back and back again from two similar surfaces, gradually loses the false glare, and becomes subdued; shining ever more and more strongly with that tint which is of its own true and inner essence. And here it may be the case that what little light finds entrance is reflected over and over again, beaten back and back with repeated buffetings from the cold grey walls of the opposing sides of the chasm; so that all false glitter, and mere blaze being eliminated, it shines in its own true tints, and with "chastened" splendour. And truly if the buffetings of the world could only educe from the character such soft sweetness as that which hangs mistily in the outer cave of Smoo, one might willingly, after presenting the one cheek, turn and exclaim—"this is the other, now."

It is in such light, that the pillars and fallen masses of rock, draped in their lichen-grayness and fernery of green, are steeped,—upon *one* side of the Cave. Upon the *other* they are not steeped, but drenched in dews which come not from heaven, but from——well, from an opening which looks very like one of the gates to it.

This is not only the other side of the Cave, but it is very decidedly the other side of the picture also. Blackness is blacker than blackness itself, when there is white near it, or mixed up with it; this is the case in the west wall of Smoo Cave. From forth of a perforation like a cathedral-window, but black as night, there roll and gush volumes of white misty vapour,—flung like snow-drift upon the dark night;—issuing unceasingly, as if the store of energy which propelled them was infinite; and backed within the gloom, by the crash and thunder of falling waters.

In order to ascertain the cause of all this turmoil, it is necessary to procure a boat; for a strangely-boiling chaldron intervenes in front of and below the only apparent entrance to the gulf within. That this is, apparently only, the sole entrance, is evident, as the boiling pool in front,(whose waters hold a direct course to those of the wall-sided geo), must have an underground connection with those heard thundering within the gulf of darkness.

The subaqueous scenery here consists of some perforation, situated immediately beneath the great steam-hole which is visible above, and from which it is separated by an arch of rock. This arch is in part submerged. The perforation as a whole has thus much of the form and appearance of a great mark of exclamation—!—of which the dot is subaqueous, the dash subterraneous. It would seem as if nature, in order

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to emphasize the strangeness of her working, had breached the partition wall, with a rent bearing the similitude of the sign of wonder.

On being launched into the inner chaldron, the first sensation experienced is "that you are about to fall down into some abyss; though the least consideration is sufficient to show that this is impossible in a boat." The second is a desire to ascertain in some degree where you are; being dimly conscious of the fact that it is not exactly water which is beneath you, nor exactly air which is above. What little light there is, whereby you ascertain this, emanates from an apparently glowing shaft, which seemingly radiates moonbeams; but which is ever emitting angry corruscations; corruscations which, smiting you in the face, you discover to be water. As the rapidly-dilating pupil admits more light, the shaft resolves itself into a lashing and waving cataract, thrown from some mysterious source, which seems mantled by gloomy skies.

The dome-shaped roof of this hidden hollow of the land, is nearly a hundred feet above its floor, and the falling waters are precipitated, from a height of eighty-five, through an orifice, which in flood they nearly fill. Some sixteen feet from the bottom, they strike upon a shelf, from which they are dashed in fan-shaped jets;—these, crossing at every angle, become pulverised into water-dust; while the smitten waters of the gulf itself, lashed into hissing foam, surge in whirling waves against the sides of the chaldron, from which, beaten back tumultously, they again converge, clashing against those of the outward flow, and conspiring, as it were, to give meaning to the expression "a hell of waters."

Such is what is gradually *felt* to be what is going on around; for, from the violent dashing of the water from every side, the eye is nearly useless,—the ear is stunned, and the feeling is puzzled, everything around being as wet as we are ourselves. For, aside of the utter contempt which Smoo evinces for Macintosh, the strange and perfectly-palpable mixture, or it may be called *emulsion* of air and water around, is potent in discovering the weak joints of the armour, and finding its way to the skin.

There is a second small opening in the roof of this cavern, through which light might enter, if it could; which in such circumstances it cannot. The opacity of fogs to light is well known, and the water-dust within, is very much more opaque than fog; indeed it will be seen, by anyone who stands above, and who regards the vapour gushing from the gash, to reflect the light almost as snowily as do the mammilated rolls of a fleecy cloud.

But Smoo's wonders are not ended. Nature has written *another* mark of exclamation on that wall which is directly opposed to the first.

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Nay, more; as if to *invite* to further search, the writing upon this wall has been lifted clearer to the light; so that the dot of the point of exclamation is, on this side, partly above water. The rib of solid rock, which gave trouble in placing the boat in the cavern, in the first case, is here lifted overhead, and there is a continuous water-floor from where we are, to whatever may be within. But, though the arch of rock is, upon this western side of the cave, curved *overhead*, it is so only if the head assume a position lowlier than its wont. We must lie down in the bottom of the boat. There need be no hesitancy, on account of the quantity of foam which has overlapped its gunwale, inasmuch as we are thoroughly wet already; a fact which excitement alone prevents us from recognising.

This second water-floored cavern, though very much larger than the first, is more of the nature of a crevice. There is depth of water for the boat to advance for some short distance, when it is quitted; and the washed-out rent is traced westward and upward,—the explorer having to walk deliberately up the bed of a rapidly-running stream. He is suddenly arrested by three things. First, by a black pool which occupies the full width of the passage. Next by a cascade which falls from the south, into that pool from some height,—this also occupies its full width. And lastly, by the continuance of the rent or passage, or cave,—whichever it be regarded,—at right angles to its previous course; and that in so diminished a height as to cause him to hesitate as to advancing further, even supposing he could surmount obstacles one and two. As to the pool,—it is just as ugly a looking hole as could be seen; an oar finds no bottom, even when sent below the water with a mighty swish. As to the cascade,—condense Lodore in height,—not in width,—and apply to it all the adjectives which a once well-known poet fantastically picked out of the dictionary to irritate still more that fussy stream, and you would still feel a want in describing this. As to the continuance of the cave which is still the bed of the burn,—it is one of those pipes, several of which the writer has noted as being connected with dogs; dogs which have gone through them, and come out minus their hair; and up which pipers have gone, and never come out at all. All of which,* the reader is not expected to believe, for the best of all reasons, namely, that the writer does not believe one word of it himself.

And yet after all, this pipe is better than the most of these, for it *has* got another end. In wading up the bed of the burn, many lumps of peat are to be seen. And what is there worthy of regard in a lump of peat, lying in the bed of a burn? Nothing in general; but the

* Dogs and Pipers

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nearest spot where the peat-bog comes to this place is more than two miles distant; and these pieces of peat have therefore done what the spectator has neither done or probably could do;—they have *explored the pipe*.

Little or nothing of what has been described will be seen by those who visit Smoo Cave when its stream is not in flood. It were as unreasonable to expect it,—nay, it were more unreasonable to expect it, than it would be to expect to behold a fair scene from a mountain top, at dead of night. For, whereas light only *discloses* the scene from the mountain top, the rush of waters into the cupola-cave of Smoo, both *purveys* the light, which most fittnigly discloses the scene,—dragged down in its own mass and radiating therefrom like the jet from a water-sheathed electric-lamp,—but it is also itself the source and power of all that which is most worthy of being seen.

After it has been visited while in full force, by all means should it be revisited, during what may be termed its calm; especially if the configuration and mode of formation of the Cave is to be considered. The judicious employment of magnesian wire will then educe *a spectacle*, wondrously grand in its way. But to see it *first* in such a manner, would most assuredly rob it of that glamour-might, which lies embosomed in its light-dispensing waterspout; and present it shorn of all that tremendous clash and conflict, which makes its grim depths such a "naughty place to swim in."

As the mode of formation of this strange chasm is closely connected with geologic cataclasm, its consideration is deferred until the limestone of the district is spoken of.

The writer would just say in parting with it, that he considers the Cave of Smoo as being *beyond measure* the most wierd and wonderful sight which he ever beheld; and he understood his companion, who has seen very much more of the world's strange sights than he has, to be of the same opinion.

The series of very diverse, and on the whole markedly schistose rocks, which go to form what has been called the Upper Gneiss, cannot be said to be characterised by any special type of hill.

The first I notice is the somewhat dome-shaped Ben Hope. It is only a dome when viewed from the eastward, for it is precipitous to the west. This hill is formed of a very loose and fissile mica-slate. Where exposed in cliff-escarpment it is disintegrated, in consequence of the openess of its foliation. Runlets of water have cut gashes in its bold western front, and the fall of the loose foliæ of

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BEN HOPE. BUTTRESSED MICA-SLATE.

M. F. H. Del.

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the stone has accuminated the upper parts of each intervening prismatioidal mass of rock; so that we are now presented with perhaps the finest illustration in Scotland of *a buttressed hill.* But here they are the buttresses of disintegration, formed out of weakness; though like other buttresses, they also tell of internal weakness. (*See sketch of Ben Hope.*)

Another hill of this formation I note, for the consideration of those who do not believe that falling-waters are potent to cut out valleys. It is Ben Hee. It has a hideous shape,—very like a Whale. That portion which performs the function of the neck, may be described as a stepped precipice. Upon examining this it will be found that the stream, which flows south-eastward, has been gradually running away with the material of the hill, and eating backward into it; undermining it at the same time, by having got a hold of an unusually shaley bed.

The superincumbent mass of rock is slipping into the corry; rending itself in the so doing, by a series of huge cracks; these, extending downwards, as each slice slips a bit lower and still lower, gape with hideous width,—a trap for snow, sheep, or the incautious foot which may be too inquisitive upon their crumbling lips.

The hills of Old Red Breccia which clustre round Tongue are of rounded outline and devoid of beauty; though, where cut into cliffs, as at Cnoc Veecdan, the forms are both grotesque and bold.

It would have sufficed to remark of the outliers, which remain as isolated remnants of a somewhat superior bed of this formation, that they have the ordinary heavy rounded form of Old Red Sandstone hills, had it not been that one of these forms "an honourable exception," and is beautiful exceedingly. This is Ben Griam Beg. Its big brother is not an honourable exception, for it is typically lumpish; yet there *it* stands, the parentage and the upbringing unquestionably the same; and so near do they stand to one another, that one cannot conjecture wherein lay the difference in their sculpturing, which opposed the noble form of the one hill, to the altogether tame and ignoble outline of the other. (*See sketch of Ben Griam Beg.*)

Griam Beg, being somewhat of a crag-and-tail hill, would be held by some to vouch for scour from the west.

Still one class of rocks, and but one hill of that class remains to be noticed,—the "volcanic" Ben Loyal.—(Laoghal).

Thinking of Scotland's Hills, we ever return to *this* as the Queen of All. For gracefulness, chasteness, versatility, and nobility of form, it stands pre-eminent.

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It is more difficult to name *the King*; but we incline to a hill in Perthshire, when viewed from the shoulder of Ben Yoss; a hill, strange enough, of the same name,—Ben Laogh.

Ben Loyal is, more than any other hill in Scotland, an *Aiguille* hill. Not that there are aiguilles *upon* it, but it is *aiguille-formed* itself. Not a single projecting horn, like Teneriffe, Yan Mayen, or Scuir na Caiche; it would not be so fine by many times if it were; but it has many peaks, is in fact set round with peaks.

What can be finer than its northern face,—round about whose feet the loving birches cling, creeping closely up and up, till they find it is no use attempting more; for it is unapproachable! What more independent and grandly assertive than its western horns,—which seem as if they had shot up through separate throats, and had been congealed in the very heavens;—like sun-flames of hydrogen, photographed while yet they flash. What more enticingly mysterious than those corries and gulfs of blue haze, which separate peak from peak! And then the *setting*:—all the accessories are fine; the wavy outlines of the lesser hills which cluster to form a middle-distance, and the winding bay with its stretches of sand, banded with bright-green waters.

And then the mystery of *its being*. Not of its birth. Wonderful to relate, geologists have not quarrelled about that: they are ready enough to do so about granites generally; but about this granite they have not. Our own belief is that it has proved too beautiful to quarrel about.

Not of its birth; not of its death; that has not come yet, and we at once exclaim "Oh, Queen! live for ever!" But of its having, with these sharp serrated outlines, resisted the scour and sweep of the devastaters which ground down the table-land around it, and left the two Griams standing,—just as it were to show what they had done elsewhere.

Its hardness and unalterability would enable it to endure; but not to preserve such peaks, sharpened like tongues of fire.

Sooth to say, while contemplating this hill, one's energies are so absorbed in admiration, that there is no place for geognostic speculation concerning it;—and it is moreover hard to have to anatomise the thing we love. Murchison draws it as eruptive, turning up upon its flanks the adjacent rocks; nowhere was the writer able to perceive any evidence of such disturbance. What did appear evident regarding it, is connected with *cold*, not *heat*. It is impossible to believe that the great ice-sheet which by some is held to have scoured over

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. delt.) (W. Lith. ft.)

Ben Yrival. —— Assynt.

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all Scotland, ever topped these summits, and left such rough and rugged lines behind it.

In presence of those high angles and serrated ridges, and in presence of the lower rounded Stomino to lee of it, and above all in presence of the Skerry and Stack standing with similarly accuminated shaft above the waters, it is much to be suspected that far less of the grinding and wearing down of the waste midlands of Sutherland was the work of ice sliding in solid mass over the land, than of the wash of waters, and the scour of ice *floating among the shallows*, and pushed over the lesser heights.

That Stomino is glaciated is at once conceded; but its glaciation is an old story; for its sweeping curvatures pass under the scanty bands of Old Red Conglomerate which, with cliffy fringes, hang on to its skirts:—though it is not contested that *recent* glaciation may not have had much to do with the late scalping of its bared head,—a glaciation which very possibly was cradled among the opposing summits of Loyal.

It is not easy to say what is the angle of the peaks of Loyal; they would seem to be about the steepest, not to be *cliffs*, in Scotland. The clinometer does not much help here; because on the spot, one has enough to do to hold on, and not go to the bottom in a single slide; and when measured from a distance, on account of the over-lapping of several slopes, too low a result is got.

The camera is still worse. Justice without mercy, defines its portraiture performance; and in "performing" among the hills, it is sadly wanting even in the first. The lowering of angles, and taming down of distant hills so much complained of regarding it, is, as regards the former, probably due partly to the overlapping mentioned, and partly to our own *hankering after the extreme*, and so, picking out the steep bits for storing in our memory; while the camera on the other hand, very probably placed in the position which suits the whole hill, foreshortens the acuter angles. The *taming down*, again, which is indubitable, is probably due to this, that the lens of a camera has not the same *penetrative power* as the human eye, nor has it any power whatever in *resolving* aerial perspective.

While the penetrative power of an "object glass" is an actual defect,—though a most useful defect,—the penetrative power of the human eye depends upon an extra adjustment, or set of adjustments of such wondrous mechanism that it is very doubtful if any human mechanist could ever produce it. This he could do certainly neither in the space, and still less, so as to operate in the time necessary for the working of the adjustments, that the Great Mechanist has.

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The "*penetration*" of a lens is a *fixed defect*,—being the name adopted to express its possessing a limited zone within which there is a near approximation to perfection, though no one absolutely perfect focus; the glass of greatest penetration being that which has a comparatively wide space of partial perfection.

The penetration of the eye is a *moveable perfection*; the limits of which extend from the seeing a fly upon the point of one's nose, to the counting of the stars in the Pleiades.

In taking photographs of scenery, therefore, when the lens is best focused to a certain distance, all the others must be more or less out of focus; and the steep angles of distant hills are merged into one another, and softened down by blurring.

In transmitting a picture to the retina which volition has commissioned it to record, the experienced eye does not focus, for more than the briefest fraction of time, any one part of the scene, but wanders over the whole, focussing near and far alternately with marvellous rapidity. The nerve all the time imprinting every perfectly focussed point upon the optic memory, which retains each and all sufficiently long for a perfect picture to stand forth. If the eye be focussed upon one point without moving, or *thus* travelling over the whole length and breadth of the view, all the rest of the picture is out of focus and blurred; and the side objects are hardly recognisable.

Aerial perspective—which John Phillip delighted to talk about, but in which Arthur Perrigal apparently does not believe,—would appear to be largely due to the presence of dust in the air; for after rain it is hardly perceptible. As the far-off is then brought so near that tints blende, there is no such perspective at all; and the pleasing softening effect, and that graduation of indistinctness which alike teach of distance, are, in the cleansed atmosphere, nearly altogether gone.

It would appear, therefore, that it is not distance which "lends enchantment to the view,"—but *dust*; and, indeed, it is difficult to understand how *distance* could lend enchantment to anything which is either pleasant or pretty; or dust either, for that matter.

Photographic lenses have as yet made very little progress at resolving that which is behind the dust; and cross-lights mystify them entirely: and here it is that the eye has its great advantage; for it *can* focus through that cobaltic-veil which the beams have flung across the picture through yonder opening in the hills; and read the wrinkles in those sun-lit crags, even through that blaze of evening glory.

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XII.—*Action of Organic Acids on Minerals.*

By Prof. H. Carrington Bolton.

CHEMISTS have long employed the commoner organic acids, especially acetic, oxalic, tartaric, and citric acids in mineral analysis, but with few exceptions they have overlooked the application of these acids to the decomposition of minerals. Acetic acid has been used to separate minerals from their matrix of calcite; Karsten (*Archiv. of Min.* XXII, 572) and Sterry Hunt have used it in the proximate analyses of mixtures of calcite, dolomite, and magnesite; calamine and willemite are sometimes distinguished by the gelatinization of the former with the same acid; Dr. J. Lawrence Smith (*Am. J. Sci.*, [2] XX, 244) has noticed the solubility of anglesite in ammonium citrate; W. B. and R. E. Rogers (*Am. J. Sci.*, 1848) have made experiments on the solubility of minerals in water containing carbonic anhydride; but there is no record of any systematic investigation of the action of organic acids on minerals with a view to the determination of species.

The following research was suggested by the difficulty of transporting liquid mineral acids on mineralogical journeys, and the need of a substitute in solid form. A few preliminary tests showed that tartaric and citric acids possess far greater power to decompose minerals than is commonly imagined, and demonstrated the desirability of extended study. Accordingly we selected and prepared for treatment, by the methods to be described, 225 specimens of minerals of whose purity and authenticity there was no doubt; these represent 200 species, their names are given in the accompanying table. For convenience these minerals may be divided into five groups, viz.:—I, *Carbonate;* II, *Sulphides, Arsenides,* &c.; III, *Oxides;* IV, *Silicates;* V, *Sundry Minerals,*—including phosphates, sulphates, arseniates, native metals, &c.

Reagents Employed.

The organic acids employed in this research were chiefly citric, tartaric, and oxalic; a few tests were also made with malic, formic, acetic, benzoic, pyrogallic, and picric acids. Of the solid acids the solutions used were saturated in the cold; citric acid being the strongest in its action was more exhaustively studied than the others.

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The behaviour of the minerals with these acids was studied in a simple manner; the finely pulverized specimens, freed from gangue, were treated in test-tubes with the reagents both cold and boiling. In certain cases the gases disengaged were examined by test papers; and the filtrates with appropriate reagents, whenever decomposition was not otherwise evident.

Having observed that a strong solution of citric acid decomposes (*a*) sodium nitrate, (*b*) potassium iodide, and (*c*) ammonium fluoride,—setting free nitric acid, hydriodic acid, and hydrofluoric acid respectively, we applied these reactions to the decomposition of those minerals which resist the action of citric acid alone. We will briefly describe these reactions.

(*a*) When solid sodium,—potassium—or ammonium nitrate is added to a boiling solution of citric acid (also tartaric and oxalic acids), on reaching a certain degree of concentration nitric acid is set free, which immediately reacts upon the organic acid, liberating carbonic anhydride and nitric oxide. If we admit the formation of oxalic acid, the reaction may possibly proceed thus:—

$$11\ H_3C_6H_5O_7 + 16\ KNO_3 = 8\ K_2HC_6H_5O_7 + 3\ H_2C_2O_4 + 17\ H_2O + 12\ CO_2 + 8\ N_2O_2$$

This mixture of reagents, which for convenience we shall designate the "nitrocitric mixture," proved to be a very powerful oxidizing solvent, as is shown in column I of the accompanying table.

Potassium nitrite decomposes citric acid in a similar manner,—the action beginning in the cold, and proceeding with energy.

(*b*) The well known facility with which even the weakest acids decompose potassium iodide, and the instability of hydriodic acid, makes the mixture of the solid salt with citric acid a very strong solvent of several classes of minerals. We call it for convenience the "iodo-citric mixture."

(*c*). When ammonium-fluoride is added in solid form to a concentrated solution of citric acid, and heated, a mixture is obtained which attacks silicates with considerable power. The tests are of course made in platinum vessels. Partial decomposition is ascertained by testing for fluoride of silicon with a moistened rod. Since, however, we have carried on this research largely with a view to *field-work*, we have examined only a few minerals with this mixture, and we omit these reactions in the table.

Behaviour of Carbonates.

All the natural carbonates examined dissolve with effervescence in cold or hot solutions of the organic acids named above.

Citrates being in general more soluble than tartrates and oxalates, citric acid attacks the minerals more strongly. Oxalic acid, however, yields precipitates, some of which are characteristic of the bases contained in he minerals; thus calcite is decomposed with formation of white pul-

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verulent calcium oxalate, which appears amorphous under the microscope; witherite yields beautifully feathered crystals of barium oxalate; siderite gives a pale yellow granular ferrous-oxalate, appearing under the microscope in the form of minute prisms, having a basal termination; and cerussite yields a heavy white precipitate of lead oxalate.

Acetic acid acts energetically; in fact glacial acetic acid does not attack calcium carbonate even on boiling; but decomposition begins at once on adding one fourth part of water. Formic acid acts similarly, and yields with cerussite a white, lustrous, crystalline deposit of lead formate.

Since all the carbonates are decomposed by citric acid alone, we did not examine their behaviour with the nitro-citric and iodo-citric mixtures.

Behaviour of Sulphides, Arsenides, etc.

Natural sulphides are very unequally decomposed by citric and other organic acids. Of the 35 species examined, five are attacked by citric acid alone in the cold, with liberation of sulphuretted hydrogen, and five are attacked on boiling the solution.

All the remainder are rapidly decomposed by heating with the nitro-citric mixture, except realgar, orpiment, cinnabar, molybdenite and proustite; of these the first three yield to the iodo-citric mixture, but molybdenite and proustite completely resist these reagents.

The decomposition of the natural sulphides by the nitro-citric mixture, affords a very interesting reaction; taking pyrites for example, the solution obtained contains ferric sulphate, and hydro-potassium citrate, while both nitric oxide and carbonic anhydride are abundantly evolved, consequently the reaction may possibly proceed as in the following equation:—

$$4\,FeS_2 + 26\,KNO_3 + 12\,H_3C_6H_5O_7 = 2\,Fe_2(SO_4)_3 + 2\,K_2SO_4 + 11\,K_2HC_6H_5O_7 + 15\,H_2O + 13\,N_2O_2 + 6\,CO_2$$

Oxalic acid mixed with potassium-nitrate acts similarly, and the reaction may be expressed thus:—

$$6\,FeS_2 + 32KNO_3 + 29\,H_2C_2O_4 = 3\,Fe_2(SO_4)_3 + 3\,K_2SO_4 + 26\,KHC_2O_4 + 16\,H_2O + 16\,N_2O_2 + 6\,CO_2$$

Certain sulphides treated with these reagents behave in such a way as to furnish additional means for their determination. Thus pyrrhotite and bornite are decomposed by citric acid alone, while their kindred compounds, pyrite and chalcopyrite (as well as chalcoite) are not attacked.

Since galenite is readily attacked and argentite is not, citric acid may be used to detect a mixture of the former with the latter. Pyrargyrite is decomposed by the nitro-citric mixture, while proustite wholly resists. When galentite is heated with the iodo-citric mixture, the mineral is

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completely decomposed,—sulphuretted hydrogen being evolved, and yellow lustrous flakes of plumbic iodide are formed; this characteristic precipitate also forms when bournonite is treated with the same reagents.

The most surprising result, however, is the decomposition of cinnabar by the iodo-citric mixture; this mineral is attacked even in the cold, and on heating the reaction proceeds with violence; on cooling the solution deposits scarlet crystals of mercuric iodide.

When cinnabar is heated with oxalic acid and potassium iodide, the action is even more energetic than with citric acid.

Sulphur is attacked by the nitro-citric mixture with difficulty, sulphuric acid being found in the solution.

The most easily decomposable sulphide seems to be alabandite, which is strongly attacked by citric acid alone in the cold. The reactions of the selenides, tellurides, arsenides, etc., are indicated with sufficient fulness in the table,

Behaviour of Oxides.

This group includes such refractory minerals as corundum, rutile, cassiterite, quartz, and others, which naturally resist these methods of attack. A few oxides are more or less perfectly decomposed, as shown in the table; the decomposition of the manganese oxides is very complete, and is accompanied with oxidation of the organic acid used. The addition of sodium nitrate does not greatly increase the energy of the solvent, as respects oxides, except in the case of uraninite, which dissolves completely.

The iodo-citric mixture applied to oxides, affords no especially notable results.

Behaviour of Silicates.

In its action on silicates, citric acid differs from hydrochloric more in power than in kind; those silicates which are decomposed by the mineral acid, with or without the formation of a jelly, are also attacked by the organic acid. Of the 76 species examined, 21 are decomposed in the cold, 14 on heating with citric acid, 12 are partially attacked by the iodo-citric mixture, and 29 resist these methods of attack; the names are given in the table. The most easily decomposed are the hydrous silicates of the Zeolite group.

Tartaric acid acts much like citric acid, as respects the silicates; but oxalic acid is less powerful. By treating silicates in platinum vessels with a strong hot solution of citric acid, to which ammonium fluoride is added, many of them dissolve very easily.

Behaviour of Sundry Minerals.

Under this head are grouped 38 minerals, whose behaviour is as varied as their composition. They include fluorides, phosphates, sulphates,

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tungstates, columbates, etc., the reactions of which are shown in the table. We observe that all the phosphates are quite readily decomposed by citric acid alone; the fluorides are not attacked; of the tungstates wolframite is slightly attacked by citric acid, hübnerite yields to the nitro-citric mixture, and scheelite resists all the reagents. Gypsum seems to be somewhat more soluble in solution of citric acid than in water, but the sulphates of the other alkaline earths are insoluble. Wulfenite and crocoite are strongly attacked on boiling with citric acid. The native metals, silver, mercury, copper, arsenic, antimony, and bismuth, dissolve with more or less facility in the nitro-citric mixture; the energetic solvent-power of this reagent is further shown by the fact that it also dissolves lead and tin.

Summary of Results.

The accompanying table, to which we have frequently referred, summarises the results obtained by the application of these reagents to two hundred minerals. From this it appears that citric acid has a power of decomposing minerals little short of that possessed by hydrochloric acid, and this difference in degree evidently gives the organic acid an advantage over the mineral acid in the determination of species. Many of the reactions are characteristic, yet we do not regard the table as a scheme for determining minerals.

That this table is entirely free from errors we dare not claim; without a fuller investigation than time allowed, it is, in certain cases, difficult to ascertain whether a mineral is merely attacked (one or more constituents being partially removed by the solvent), or whether it is truly *decomposed.*

Application to Field Work.

The advantages of these methods in the examination of minerals and rocks *in the field* are evident. Many geologists and mineralogists add to their outfit for blowpipe work, a glass bottle of hydrocloric acid, carried in a protecting wooden case, for the purpose of testing carbonates; but notwithstanding great care, the fragile glass often gives rise to unhappy accidents. To avoid such inconveniences, we propose to substitute for the liquid acid, the solid citric acid, which can be readily carried in a strong pasteboard box, and dissolved in water obtained in the field, when required for use. The facility with which potassium nitrate (or nitrite) is decomposed by citric acid, makes it possible to carry nitric acid also practically in a solid form; and the addition of solid potassium-iodide to this list of *dry reagents* for *wet analysis*, greatly increases the means of studying the chemical characters of minerals in the field.

Hydro-potassium sulphate,—furnishing sulphuric acid in a solid form—has already been proposed by E. Jannettaz (*Compte Rendu*, 1874).

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The writer has tested in the field the methods above described, applying them to the more common minerals with success. For the purpose of working with solutions, a nest of test tubes (12 c.m. long) in a cylindrical pasteboard case is found convenient; the innermost test tube may be used to hold pulverized citric acid. In the absence of test tubes, the writer finds the hollow palm of his hand a convenient and portable apparatus for testing carbonates by their effervescence.

Application to Geological Phenomena.

The disintegration and erosion as well as the consolidation of rocks has been attributed in part to the chemical action of various solvents, among which carbonated waters play an important rôle; if, however, we are permitted to reason by analogy, it appears probable that many changes, imperfectly understood by geologists, may be explained by referring them to the action of the organic acids of the soil. If citric, tartaric, and oxalic acids are able to decompose minerals, rapidly and completely in the hands of the chemist, may not humic, geic, crenic, apocrenic, and other acids of humus, in the lapse of long periods of time, accomplish much in the disintegration of rock-material on the surface of the earth?

The very existence in the soil of compounds of ulmic (?), humic, crenic, and apocrenic acids, with ammonia, soda, potassa, lime, magnesia, alumina, iron, and manganese, is *proof* that these organic acids exert considerable influence. This is also shown by the existence of minerals, of which organic acids form component parts;—such as whewellite, thierschite, succinite, mellite, pigotite, etc.; as well as the occurrence of limonites, containing 12·5 to 15· per cent of humic acid (Sterry Hunt, Geol. Canada, 1863, 510); and of acid hydrocarbons, containing the ill-defined bodies, geoceric, georetinic, and butyro-limnodic acids.

Paul Thénard has remarked the extraordinary power of azo-humic acid to dissolve silica (*Compte Rendu* LXX, 1412,); Bischof, Mülder, Herrmann, Detmer, Seuft, and many others, have recorded observations on the geological action of the acids of humus; these notices are widely scattered throughout Journal literature; and, since we began these researches in the laboratory, our friend Alexis A. Julien, of Columbia College School of Mines, New York, has collated all papers bearing on this subject, and has recently published a review of them, together with the results of original study, under the title "Geological Action of the Humus Acids." This will be found in the Proceedings of the *Am. Assoc. Adv. Science*, vol. 28, 1879 (80).

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TABLE SHOWING THE BEHAVIOUR OF CERTAIN MINERALS WITH CITRIC ACID ALONE, AND WITH REAGENTS.

I.

DECOMPOSED (IN FINE POWDER) BY A SATURATED SOLUTION OF CITRIC ACID.

1. IN THE COLD.

A. *Without evolution of Gas.*	B. *With liberation of CO_2.*	C. *With liberation of H_2S.*	D. *With separation of SiO_2.*
Clausthalite	Calcite !	Stibnite	Wollastonite
Leucopyrite	Dolomite*	Galenite	Rhodonite !
Atacamite	Gurhofite !	Alabandite !	Chrysolite
Brucite	Ankerite*	Sphalerite	Willemite ! ‡
Gummite	Rhodochrosite*	Pyrrhotite	Nephelite
Pyromorphite*	Smithsonite *		Lapis lazuli
Mimetite	Aragonite !		Chondrodite
Triphylite	Witherite !		Pectolite !‡
Triplite	Strontianite !		Laumontite !‡
Vivianite !	Barytocalcite !		Chrysocolla !
Libethenite !	Cerussite !		Calamine !‡
Olivenite !	Malachite !		Apophyllite
Pseudomalachite	Azurite*		Thomsonite !
Wavellite			Natrolite !‡
Pharmacosiderite !			Mesolite !
Torbernite			Analcite
Autunite			Chabazite
Ulexite !			Herschelite ‡
Cryptomorphite !			Stilbite
Anglesite			Deweylite
Brochantite !			Prochlorite

2. ON BOILING.

E. *Without evolution of Gas.*	F. *With liberation of CO_2.*	G. *With liber on of H_2S.*	H. *With separation of SiO_2.*
Cuprite !	Hausmannite †	Bornite	Tephroite ‡
Zincite	Pyrolusite !†	Jamesonite*	Ilvaite
Malaconite	Manganite†	Bournonite*	Phlogopite*
Goethite*	Psilomelane !†	Boulangerite	Datolite !†
Limonite*	Wad !†	Kermesite	Prehnite*
Allanite (?)	Magnesite !		Heulandite
Apatite*	Siderite !		Serpentine
Wolframite*			Chrysotile
Wulfenite			Retinalite
Crocoite			Bastite
Gypsum*			Genthite
			Gieseckite*
			Jeffersite
			Masonite*
and those in A.	*and those in B.*	*and those in C.*	*and those in D.*

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II.

DISSOLVED BY BOILING WITH CITRIC ACID WITH THE ADDITION OF:—

I. *Sodium nitrate.*		K. *Potassium iodide.*	
Silver	Cobaltite !	Realgar*	Pyrope
Mercury	Ullmannite !	Orpiment*	Colophonite
Copper	Marcasite !	Cinnabar !	Epidote
Arsenic	Arsenopyrite !	Hematite*	
Antimony	Nagyagite	Menaccanite*	
Bismuth	Covellite !	Washingtonite*	*and most of those in A, B, C, D, E, F, G, H, and I.*
Sulphur *	Berthierite !	Magnetite*	
Bismuthinite	Pyrargyrite	Franklinite	
Domeykite !	Tetrahedrite !	Braunite	
Argentite	Tennantite !	Enstatite	
Hessite	Stephanite	Paulite	
Chalcocite !	Polybasite !	Augite	
Tiemannite !	Enargite !	Spodumene*	
Millerite !	Uraninite !	Hornblende*	
Niccolite !	Hübnerite	Actinolite*	
Pyrite !		Pargasite*	
Chalcopyrite !		Olivine	
Linnæite	*and those in C. and G.*	Almandite	
Smaltite !			

III.

I. MINERALS NOT DECOMPOSED BY THE ABOVE REAGENTS.

Graphite	Hyalite	Wernerite	Titanite
Molybdenite	Diopside	Leucite	Staurolite
Proustite	Petalite	Anorthite	Bowenite
Fluorite	Asbestus	Labradorite	Talc
Cryolite	Beryl	Oligoclase	Kaolin
Corundum	Zircon	Albite	Ripidolite
Spinel	Vesuvianite	Orthoclase	Columbite
Chromite	Zoisite	Tourmaline	Samarskite
Chrysoberyl	Iolite	Andalusite	Scheelite
Cassiterite	Biotite	Fibrolite	Barite
Rutile	Muscovite	Kyanite	Celestite
Quartz	Lepidolite	Topaz	Anhydrite

Completely decomposed or dissolved. * Feebly attacked. † The CO_2 evolved is derived from the Citric Acid. ‡ Gelatinizes.

N.B.—The gases evolved are to be examined with acetate of lead test paper, the solutions with appropriate reagents.

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XIII.—*On Substances which may prove to be New Minerals.*

By Professor Heddle.

Part Third.

Tyreeite.

My notice of this must be considered preliminary in every way. The discovery of "the beautiful carnelian marble of Tyree" has been in a late paper credited to Dr. Walker.

For some years after its discovery, it was used, or attempted to be used for mantle-pieces, and other internal decoration.

Partly on account of the minuteness of its pattern unfitting it for this purpose, and partly on account of the small quantity sent into the market, it, however, seems never to have found its way into general favour.

We find Dr. Macculloch lamenting the wasteful method of working adopted in the quarry,—the wholesale shattering of its mass by the excessive use of "Mines."

As the contrast of colour presented by its several ingredients is both striking, pleasing, and unique, the employment of it for inlaying, for letter weights, and similar purposes, undoubtedly would be now general, could it again be got.

The quarry, however, would seem to be both exhausted and ruined, and for many years not even a "hand-specimen" has been procured for cabinets.

The general mass of the marble is of an impure white very fine grain, and it has a greasy lustre. Profusely sprinkled throughout this, there occur rude crystals of *Sahlite* of the size of grains of corn. An analysis of these has been published by me in a paper laid before the Royal Society of Edinburgh. They are of a lively-green colour, singularly banded with white lines; and were, when of pale colour, at one time regarded as *corundum*. The "carnelian" tinge which characterises the rock is not uniformly diffused throughout it, but stains it, as it were, in blotches; more rarely in bands; while it sometimes is more intense around or in contact with the imbedded crystals of sahlite.

Very rarely minute highly lustrous crystals of brown *sphene*, with rounded faces, are to be seen; and still more rarely masses an inch or two in size of watery-blue *malacolite*, or of rich dark-green *augite*. The fringes of the mass rarely show *graphite* flakes, and granules of *pyrrhotite*.

The manner in which the red colouring matter is segregated, led me to examine the rock in section;—and the failure of the microscope in revealing the nature or source of the colouration, called for analysis.

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A number of ordinary specimens were dissolved in weak acid, and left undissolved a brick-red powder. From the very intense tinctorial powers of this, from its appearance, and its total want of crystalline structure, I was led to suppose it to be new;—but the very minute quantity obtained rendered it impossible to determine this.

To the kindness of the clergyman of the island I am indebted for collecting at the spot the quantity which has enabled me to determine the little that I have done regarding it.

About one and a half hundred-weight of the rock were dissolved in hydrochloric acid, diluted with water to the extent of showing only the feeblest effervesence. Sixteen gallons of hydrochloric acid were required.

There were obtained about 30 pounds of crystals of *sahlite*; about one-eighth of an ounce of crystals of *scapolite*; perhaps half that amount of *sphene*; and some ounces of a red mud, evidently very mixed in substance.

It was found that by suspending this last in a large quantity of water, the larger part of its bulk separated pretty rapidly as a dull-brown cream, consisting apparently of minute scales of talc; while the whole of the red pigment with much of the talc remained in suspension; adhering to the water with great pertinacity.

As the only mode of crudely separating these last, a series of suspensions and decantations in a large number of stoppered jars, was carried on for the space of more than a year. At the end of this, about three ounces of an impure, and half-an-ounce of an *apparently* pure product were obtained.

Operating afresh upon the purest produce, there was ultimately obtained 1·913 grammes of a powder which did not seem to be capable of being further purified by such a process.

This powder, when examined by the microscope, shewed no trace of fibrous structure;—the repeated agitations would unquestionably, however, have almost entirely destroyed such, had it ever existed. This powder was of a deep brick-red colour, and of very intense tinctorial power. Its extreme state of division precluded the employment of all methods of ascertaining its specific gravity.

When placed in strong sulphuric acid it was found that, of the 1·913 grammes, ·785 were dissolved, leaving 1·128 insoluble.

This last, when fused with Fresenius' flux, yielded, on ·65 grammes—

Silica	68·461
Alumina	no trace.
Ferrous Oxide	3·468
Manganous Oxide	·153
Lime	2·326
Magnesia	19·076
Water	6·85
	100·334

being probably an impure *talc*.

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The portion soluble in acid, yielded :—

Alumina	8·227
Ferric Oxide	38·22
Ferrous Oxide	3·158
Manganous Oxide	·394
Lime	2·211
Magnesia	29·936
Phosphoric Acid	4·713
Water	12·466
Silica	1·019
	100·344

The qualitative analysis showed minute traces of two metals which I could not determine; one of these came out at the stage when Uranium should have; but tests for that metal in no way confirmed its presence.

The red portion was totally soluble in hydrochloric acid.

I know not what to make of this substance.

In the first place the total absence of alumina and ferric oxide in the first analysis, with their large quantity in the second, indicates a perfect separation.

A chemical consideration charges us to pronounce it a mixture;—the phosphoric acid covering so small an amount of the bases. It cannot be an *ochreous* mixture, for such could not exist in primative marbles, along with such reduction-products as *graphite* and *pyrrhotite*: while again the consentaniousness of its suspension as a whole, contraindicates a mixture. I am fain to leave it in the hands of those who enjoy operating upon hundred-weights and obtaining grammes,—after splashing with water for years.

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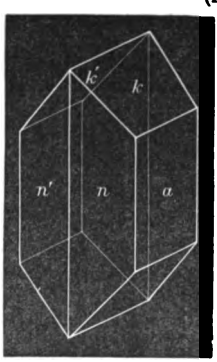
XIV.—*On Crystallized Olivine from Slag.*

By Dr. Charles O. Trechmann.

I have recently measured one of the crystals of the slag described by by Mr. A. E. Arnold, in vol. III, p. 114 of the Magazine.

Observed forms:—

Brooke and Miller. Mineralogy, 1852.	Naumann. Elemente de Min.
$a=100$	$T=\infty P\breve{\infty}$
$n=120$	$n=\infty P$
$k=101$	$k=2P\breve{\infty}$



Angles (normals)	Measured Trechmann.	Fayalite Miller.	Olivine
a : n ..	658 9′ ..	65° 12′ ..	65° 1
n : n′ ..	49° 42′ ..	49° 36′ ..	49° 58′
k : k′ ..	98° 32′ ..	98° 22′ ..	99° 7′

The angles are therefore almost identical with those derived by Miller (*Trans. Phil. Soc., Cambridge, III; Brooke and Miller, Mineralogy*, 1852, *p.* 319) from crystals found in refinery cinder, and the slags of copper furnaces, &c,—having the composition of Fayalite, *viz.*—2 FeO, SiO_2.

Making allowance for imperfection of the particular crystal measured, they seem to be intermediate between those of olivine and fayalite

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Reviews and Notices.

Sitting of the physico-mathematical section of the Royal Academy of Sciences, Berlin, October 18th, 1880. *Rammelsberg.*

Artificial Gay-Lussit.

OBLIQUE crystals, consisting of one molecule of soda carbonate, one molecule of calcic carbonate, and five molecules of water, are found in nature. Bauer showed 50 years ago, that this compound crystallized from a solution of sodic carbonate, at a temperature near that of freezing. It does not, however, appear to be known that this double carbonate is produced in considerable quantity in the manufacture of sodic lyes. These crystals, more or less impure and discoloured, are deposited at a temperature of about 40° in the vessels containing crude soda lye. Smaller white crystals are formed in the towers in which carbonate dioxide is passed through the lyes, for the conversion of caustic into commercial soda.

Dr. Arzrum has made a crystallographic and optical examination of these crystals occurring—

I. In the carbonized lye.

II. In the clear crude soda lye.

They belong to the oblique system.

$$a : b : c = 1{\cdot}4918 : 1 : 1{\cdot}4471.$$
$$\beta = 78{\cdot}46.$$

I. The type of these crystals is determined by the fairly equal development of faces $\bar{1}12$, 011 110: the faces 001 occur very seldom, and then always as slight truncations of the edges 011, $0\bar{1}1$. Faces of the first three forms are of equal lustre.

II. The predominant forms are 110, 011, 001 :—the faces of the last are frequently quite small, those of $\bar{1}12$ always so. The faces of 110 are characteristically striated parallel to the edges of 110, 011, and $\bar{1}12$: the basal plane 001 is generally unstriated.

The percentage composition of the compound $(Na_2CO_3 + CaCO_3) + 5Aq$ is 33·8 $CaCO_3$, 35·8 Na_2CO_3, 30·4 H_2O; while the purest crystals yielded 32·2, 34·2, 35·1, per cent of sodic carbonate. Not only do most of the crystals, the under parts of which are grey, yield a residue containing

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silica, when treated with acids, but the solution so obtained gives with ammonia a gelatinous precipitate of alumina and lime, free from phosphates.

Loss of soda in the process of manufacture has long been recognised, and this loss, due to formation of insoluble compounds, is proportional to the quantity of ash in the coal used. As this ash is mostly silica, alumina, and lime, silicates of alumina, lime, and soda must be formed in the furnace, and remain in the residues. Scheurer-Kestner considers the residues are richer in soda the greater the quantity of lime used in the manufacture, and attributes this to the formation of calcic sodic carbonate. The actual existence of this compound in the soda lyes is now proved.

T. W. D.

On the optical characters of the plagioclase felspars.—(MAX SCHUSTER)—*Min. a. Petr. Mitth. G. Tschermak. Vol.* III. *p.* 117.—This paper contains an exhaustive examination of the optical behaviour of the triclinic felspars—albite, oligoclase, andesite, labradorite, bytownite and anorthite. The author, starting with Tschermak's theory that all the plagioclase felspars are mixtures of the two isomorphous felspars, *albite* and *anorthite* (soda and lime felspars respectively), has investigated them for the purpose of discovering whether this theory is borne out by their optical characteristics; and concludes that "the soda-lime felspars form, with respect to their optical properties, a series similiar to that of all their other properties, and every mixture, consisting of definite proportions of the ultimate terms, has corresponding optical properties, which approach either those of albite or of anorthite, according to the proportion of these constituents."

It follows from this proposition, that, given the optical behaviour of any plagioclase felspar, its chemical composition can be at once ascertained therefrom. The character upon which the author mainly relies is the angle, which the direction of maximum extinction, in plane polarised light, forms with the planes P. and M. (001 and 010). The relations between these angles and the chemical compositions of the various felspars (in terms of molecules of albite and anorthite) are exhibited in a diagram, and from the curves thus obtained the author deduces the following equations.

Let x be the percentage of molecules of anorthite present, and y the inclination of the direction of extinction, above referred to, expressed in degrees. Then $y = a + bx + cx_2 + dx_3$, where a, b, c, and d are constant. When y is the angle between the direction of extinction and P, the equation becomes,

$$y = 5 - 0{\cdot}1752x + 0{\cdot}001457x_2 - 0{\cdot}00003905x_3.$$

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whereas when y is referred to M it becomes

$$y = 20 - 0{\cdot}5062x - 0{\cdot}008121x_2 + 0{\cdot}00007483x_3.$$

It is thus possible, given x to find y or *vice versa*, and thus the chemical composition of any plagioclase felspar is determinable from its optical behaviour; it is merely necessary to procure cleavage plates or sections parallel to P and M, to determine in them the direction of extinction, and y being thus known, to calculate from it and from the above equations the percentage of albite and anorthite which it contains.

The author finally concludes that his observations prove the truth of Tschermak's theory, and also confirm the view of Senarmont, that the optical characters of a composite salt are variable, and approximate to those of its predominating constituent.

H. L.

MINERALOGICAL OBSERVATIONS.—*On the crystallographic and optical properties of Piedmontite*—(H. LASPEYRES,) *Zeitsch. f. Kryst, un. Min. P. Groth, vol.* IV, 5. *p.* 435,—The author devotes the present paper to an examination of the physical properties of the Piedmontite (Manganiferous epidote) from St. Marcel, the chemical composition of which he has previously communicated in vol. III., p. 525 of the *Zeitschrift* for 1879.

The conclusions he arrives at are:—

1. Piedmontite is a true epidite.
2. Its crystallographic and optical characters approach very closely to those of pistacite, excepting only the absorption of light, which is, generally speaking, complementary to that exhibited by pistacite.

Crystallographic characters—From a number of determinations the author deduces the following axial relations for piedmontite:

$$a : b : c = 1{\cdot}6100 : 1 : 1{\cdot}8326 \quad . \quad \beta = 64°39'.$$

The prismatic crystals are bounded by the planes $\frac{1}{2}P\infty(\bar{1}02)$, $\infty P\infty(100)$, which predominate; and oP (001), less extensively developed. All the planes are rounded and striated by oscillatory combinations, oP being the smoothest and the most brilliant.

Optical characters—In a section of piedmontite, cut perpendicularly to the axis of symmetry, and in which the two cleavages form an angle of 64° 46′, the angle, which one of the axes of elasticity, lying in the obtuse angle between the crystallographic axes *a* and *c*, makes with the clinoaxis *a* is

32° 47′ for the Lithium flame
32°2′ for the Sodium flame.

The second axis of elasticity therefore makes with the vertical axis *c* an angle of

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7° 26′ for the Lithium flame.
6° 41′ for the Sodium flame.

and it lies in the acute angle between the crystallographic axes *a*, and *c*, at least for light rays of low refrangibility. The dispersion is thus unusually strong, the difference between the lithium and sodium flames amounting to 0°45′.

Pleo-chroism.—A section perpendicular to the axis of maximum elasticity [a] is dark-bluish red in ordinary daylight, and shews the maximum amount of absorption of light. In polarised light, this color is decomposed into a dark amethyst, for vibrations parallel to the axis of medium elasticity [b]; and a dark blood-red, parallel to the axis of minimum elastity [c].

The section perpendicular to [b] is of a bright orange-red in day-light, and shows the least absorption of light. In polarised light parallel to [c]the section shews the above-named dark bluish-red colour; and, parallel to [a], bright orange.

The section perpendicular to [c] is dark yellowish red in ordinary day-light, with medium absorption. In polarised light parallel to [a] it appears bright orange, and parallel to [b] dark amethyst.

Moreover the directions of the "axes of absorption" (*i. e.* the directions in which the differences of colour attain a maximum) do not coincide with the axes of elasticity, except in the case of the axis of symmetry; and in the plane of symmetry the axes of absorption are perpendicular to each other, and form with the axes of elasticity an angle of about 20°.

Piedmontite is positively birefringent, the angle between the optic axes, and the index of refraction being both very great.

With respect to the twinning of piedmontite, the twins are always polysynthetic and lamellar, analogous to those of the plagioclase felspars; the twin plane being mostly $\infty P\infty$ (100).

H. L.

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THE MINERALOGICAL MAGAZINE

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MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

No. 20. JULY, 1881. Vol. IV.

XV.—*The Geognosy and Mineralogy of Scotland.*

By Professor Heddle.

SUTHERLAND.—Continued.

Rock Sculpture.

NOTWITHSTANDING the very considerable extent of shore-line which the deepest-seated rock exposes to the ocean, it exhibits extremely few illustrations of either cliff, or rocky shore.

The rocks which do occur are found to be of an altitude which is altogether trifling,—very much more so than even the great durability of the material of which they are composed would warrant us in expecting. Indeed, from the fact of the shore-line being at right-angles to the strike of the strata, and from these strata being at so high an angle of tilt, we should expect to meet with an almost continuous line of cliff. Instead of this, we find long points of land, of hummocky or undulating contour, running far out into the sea,—a profuse sprinkling of cliffless islets, which resemble in every particular the hummocks of the land,—and long sinuous stretches of water thrusting themselves up into what resemble land-valleys, very much more than sea-bays.

The foremost conclusion certainly is, that the present could not have been the oldest coast line, or, indeed, a coast line for any length of time;—that had the old Hebridian land stood, through the long ages

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of its waste, at the same sea-level as now, that sea must have, in many places, cut cliffs of an altitude very much greater than those which we now find upon its shores. The fact that the glaciated contours of the land (though which of several possible glaciations, it is not easy to make out), thrust themselves everywhere beneath the waters, and sweep over the very summit of the island-rocks, may possibly be held as sufficient to account for the absence of cliffs; as the mantling ice would sheathe and shield the land from marine action. But, *that the land has sunk*, is a far more probable explanation.

The sinking of the land would submerge and conceal all marine precipices; but there is no need to conclude that soundings would disclose any such in the Minch, as the trench in which its waters now lie, might, in its middle-reaches at least, have for long been a somewhat elevated mountain-valley.

That the land *has* sunk, and sunk at two different periods in comparatively recent times, may be maintained,—*first*, from the fact that the cliffs both of the Torridon rock and of the Upper-gneiss are continued or continuous below the water-level, to a very considerable depth. As water cannot breach the land many feet beneath its low-water level, it is evident that these cliffs were cut when the land stood at a higher altitude.

That there has been so little cliff-cutting of the oldest formation in more recent times, may, in many places, be explained by its having been till recently swaddled up in the Conglomerates; and by supposing that the breaching by the sea had only gone along with glacial scour on the land, in clearing off that cover. At what may be called the Island of Sandwood, this would seem to have been very specially the case.

Again, as regards very recent subsidence, it has more than once been recorded, that in several places in bays of the Long Island, the oar of a boat may be thrust its full length into peat, which forms the upper coating of islets which never appear above the surface, even at low water. Banks of peat at the water-edge, surprise everyone who visits that country; and sand-silted bays with entombed trees, are seen both there and in the Orkneys.

There is one point, however, to which the above does not apply.

Cape Wrath would appear to have been cut at the same time that the still more lofty cliffs of the Conglomerate in its vicinity were formed; very probably it may have been of still older days; and very possibly its fellow, of scarce less noble form, may be buried in the heart of Scrishven.

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There is something about this headland which impresses one in a way which no other in Britain can. The corruption of its name of Rath, into a word which is certainly not unbefitting to its surroundings, can do little more than attract; but when it is *seen* and considered, it is felt that this is, par-excellence, *the headland* of Britain.

In the first place it is *a Cape*,—more than a mere headland. There is but one other Cape, in Britain; and that one (Cape Cornwall) neither pronounced in its dimensions, nor prominent geographically. It is not the *end of the land*. But this is *The Cape:*—the end of the land very absolutely;—and it is so on more than one side, or indeed on two, for it protrudes in self-assertive fashion; and the eye ranges, with no spot of earth to rest upon,—sweeping from the North Cape of Europe, past the ocean-road to the Pole; past Cape Farewell and Labrador, and down upon the other side, to Newfoundland; so distant, each and all, that the direct path to reach them would be *through* the Earth, and not over its surface.

And it *was this Cape:*—and it probably dominated in this self-same fashion over the waters, even when the World was very young, and the place of Europe was not known.

Of all the land which was above the waters then, there remains but very little; it has a following in the rear, which, heavily weighted, has lost its freedom; and there is that other stretch across the Minch.

Here is what Macculloch writes of it:—"There is a moment in rounding a cape of this nature that is very impressive; when the new shore is not yet opened, and when we can truly feel that we are at the limit and verge of the land, with sea on all sides; contemplating the last promontory which, boldly advancing into the waters, braves the fury of a whole ocean. It was the north western angle also of Scotland, *the land's end* of its wildest region, and the most advanced post of its wildest seas. The interminable horizon, wide-spread around, reminded us that there was nothing before us now, for ever, but sea and sky.

Nor was the impression, that we were now, as it were, launched on the polar seas, diminished by the aspect of this cape. As if nothing else could resist the fury of a northern ocean, Nature seems to have reared a huge and rude barrier which neither storms nor waves should ever have power to move. I felt how insignificant Cape Rath would have appeared, how Nature herself would have erred, had Britain here terminated in any other manner, had any lower and tamer point of land been opposed to this raging sea. Here she was truly her own poet; nor could the most vivid imagination and the most correct taste, have conceived a more thoroughly harmonious adopion of character;

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that of the wildest land to the wildest ocean, the strong-built and immoveable rocks to the furious waves;—to the majestic breaking of the lofty billows, a still more majestic pyramid, towering far above their greatest efforts; and, as the termination of the rude mountain-ranges of Scotland, a buttress worthy of all their grandeur and all their strength.

The change in the nature of the rock takes place for a short distance before arriving at this Cape, and is singularly fortunate for its picturesque character. We can feel that the effect of the sandstone cliffs, fine as they are, would have been as nothing here, compared to the noble forms of granite and gneiss which lift their broken and spiry masses against the white foam that surges against them. Here also, and nowhere else, there is a single and insulated mass of these rocks; as if Nature had especially provided them that she might guard the land from the attacks of the ocean, by a substance of unusual strength. While the cliffs are lofty, rugged, and broken into wild and angular forms, Cape Rath itself, the extreme point of the land, stands boldly out into the waves as if separated from them; a towering and noble pyramid, of three hundred feet or more in height. Nothing can exceed the elegance and majesty of its form, declining towards the sea in a second and much lower pyramidal rock; the whole forming an outline as graceful as it is unexpected, and as grand as it is appropriate." *(See Sketch of Cape Rath.)*

Still, that which most impresses is the boundless stretch of ocean to the northward. There is positively almost nothing else, round and round.

Barra, Rona, and Iceland lie to the west; the Faröes and Spitsbergen to the east; an open lane of water lies between, along which thought—skimming over the floor of Ocean and finding a way where Parry could not force his,—sweeps over what is usually regarded as the *top of the World*, glides through the opening of Behring's Straits and, but slightly vexed by the ripplings of countless Polynesian dust, sweeps still more skimmingly over Antarctic ice into the great trench of the Atlantic, and so home again after its cincture of the Globe.

The sculpturing of the rocks of this formation, so far as we can see of it, consists of the shearing off, in rugged and sometimes step-like fashion, of those smoothed and gently-moulded swellings of the land, which indicate glaciation by a ponderous sheet. *(See Sketch of Contours of Hebridian coast-line.)*

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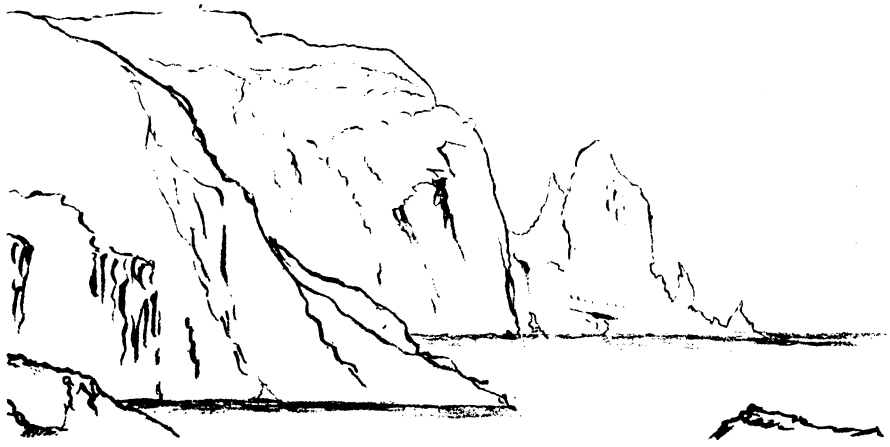

CAPE RATH.

M. F. H. Del.

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GLACIATED OUTLINE OF HEBRIDIAN GNEISS : NEAR CAPE RATH.
? OLD GLACIATION.

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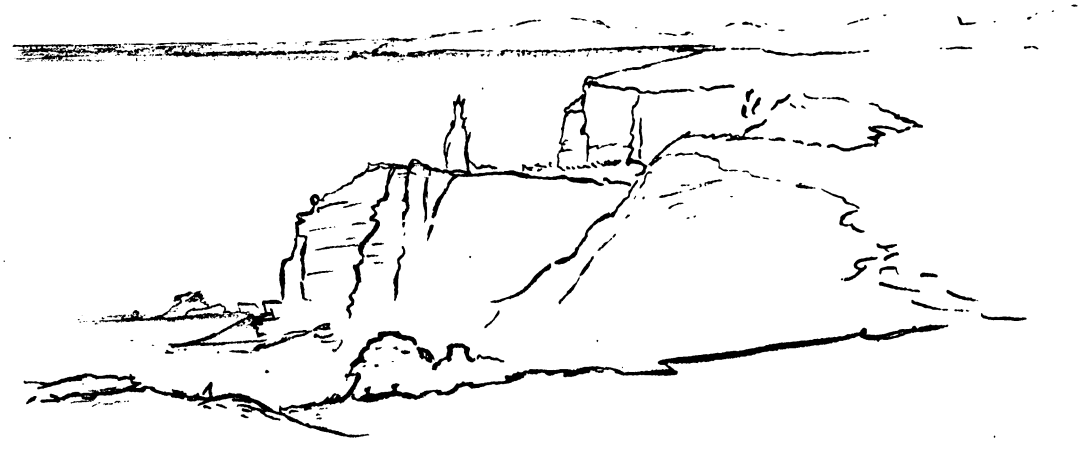

RHU VUACHIL AND ROCHIL STACK. TORRIDON SANDSTONE.

M.E.H Del.

LAKE, TRURO.

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Cliffs of the Conglomerate.

These are noble.

Though they do not possess the airy lightness of those of Foula, ıe tremendous massiveness of Hoy Head, or the savage wildness of t. Kilda, they surpass each and all of these in their diversity of ɔrm, and in their colouration. The much-praised Handa, to which ne tourist is directed by the guide books (and of which the cliffs nstead of being 700 feet in altitude, as therein stated, are under 400), s in reality both heavy in form, and tame in outline, in comparison vith those which occur *for some miles continuously*, on either side of Cape Wrath.

There is a very marked difference in the features of the two lines of cliff which stretch at right angles to one another on either side of that Cape: to which, or to the little island of Gneiss which it terminates, these cliffs act as buttresses. The rock-surface of that islet slopes steeply down to the waters, both to the east and south; and it would be cut totally off from the rest of Sutherland if it were not that the mantling sandstones act as a cincture. The coast-line of the Sandstones commences about three miles south of the Cape, and extends as an almost continuous line of cliffs to Roan Island, at the mouth of Loch Inchard. All along this line the dip is slightly seaward—towards the trough of the formation; this may be regarded as lying in the centre of the Minch.

The cliffs therefore are formed by the faces of the strike-joints: and all more or less overhang their bases.

The coast-line at right angles to this, which stretches eastward from the Bay of Kearvaig, may be regarded as formed by fractures, accordant with the dip-jointing of the rock; and, while there is a mural precipitousness, there is here no overhang.

The disrupting effect of the breaching of the sea must, in the first of these circumstances, be aided by the gravitation of the rock forwards; and, in those spots where the jointing is most free and open, the cliffs give way most readily; so that along this *western* shore the line of precipice is an undulating, and very much more varied one than that which faces the *north*, where it is almost rectilinear.

The sketch given of the Rhu Vuachil, and the shore-line running north to the Cape, illustrates the undulating *western* cliffs.

Along this line the cliffs are of ever-varying height, but are perhaps never beneath 200, or over 460 feet.

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The Clo Kearvaig, which commences the *northern* line, at once starts up to an altitude of nearly 400, where it faces Kearvaig Bay. It is here sentinelled by a twin-spired stack, perhaps the most graceful in Britain. Dr. Macculloch considers it the finest in Scotland. He writes:—"Stack a Cloa, which stands here detached at a great distance from these cliffs, forms a magnificent object. Although of sandstone, and therefore displaying that mason-like structure which I formerly noticed, I know not that any other character or mode of disposition could have produced so fine an effect.

Of all the similar pinnacles in Scotland, whether on the east or west coasts, there is not one to be compared to this for elegance of form or singularity. As far as the eye could judge, it rises to the height of 200 feet or more, immediately from the sea; the basement on which it stands being extremely narrow, but rendering the effect far more pleasing than if these spires had shot off unsupported from the water. There are two associated pinnacles, in fact, of equal altitudes and similar forms; the general outline of each being gracefully pyramidal, while that of the whole is no less elegant. They remind us of the paired spires of the Gothic Cathedral; and as if Nature had meant to preserve them from accident, they appear as if bound together at two points, by transverse blocks of stone; adding as much to their effect, as to their appearance of strength and durability." (*See Sketch.*)

Eastward of Clo Kearvaig, the cliffs run rapidly up into the two magnificent headlands of Clomore. These are 630 feet high. Of these a sketch is given, which shows the comparative rectilinearity of the northern cliff-line. At a slightly southward curvature which terminates the hill of Scrishven, the altitude of the rock-front attains to 930 feet.

The marked straightness of this shorn-off line of coast, even beyond, that is eastward of the termination of this formation, on to the Kyle of Tongue, is of difficult explanation. Indeed the same may be said of the general rectilinearity of the north of Scotland:—by some it has been supposed to indicate the close proximity of a great line of fault.

It is no cynicism to say of geologists that *where they are at fault, they often place a fault.* But this will not do here. The line of these shores is two wavy in its straightness, and it cuts with varying features through too many formations. The variation of these features, moreover accords with what would be the normal variation of the action of the ocean-lash upon each variety of rock.

We are forced to regard it as a true ocean-cut ocean-verge.

And as we do so, the mind stands appalled in the contemplation of

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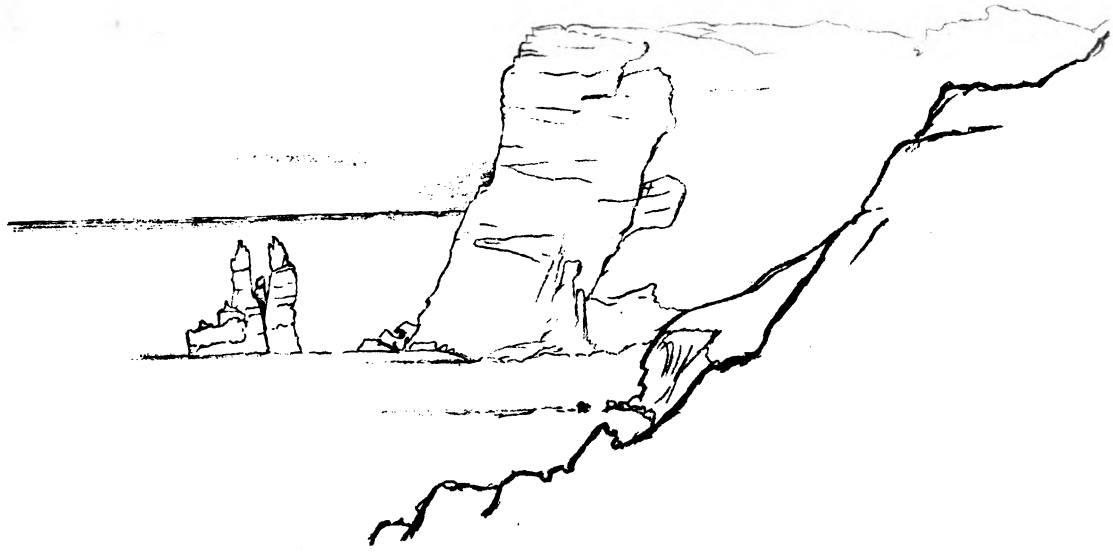

RHU KERVAIG & STACK A CHLO. TORRIDON SANDSTONE.

M.F.H Del.

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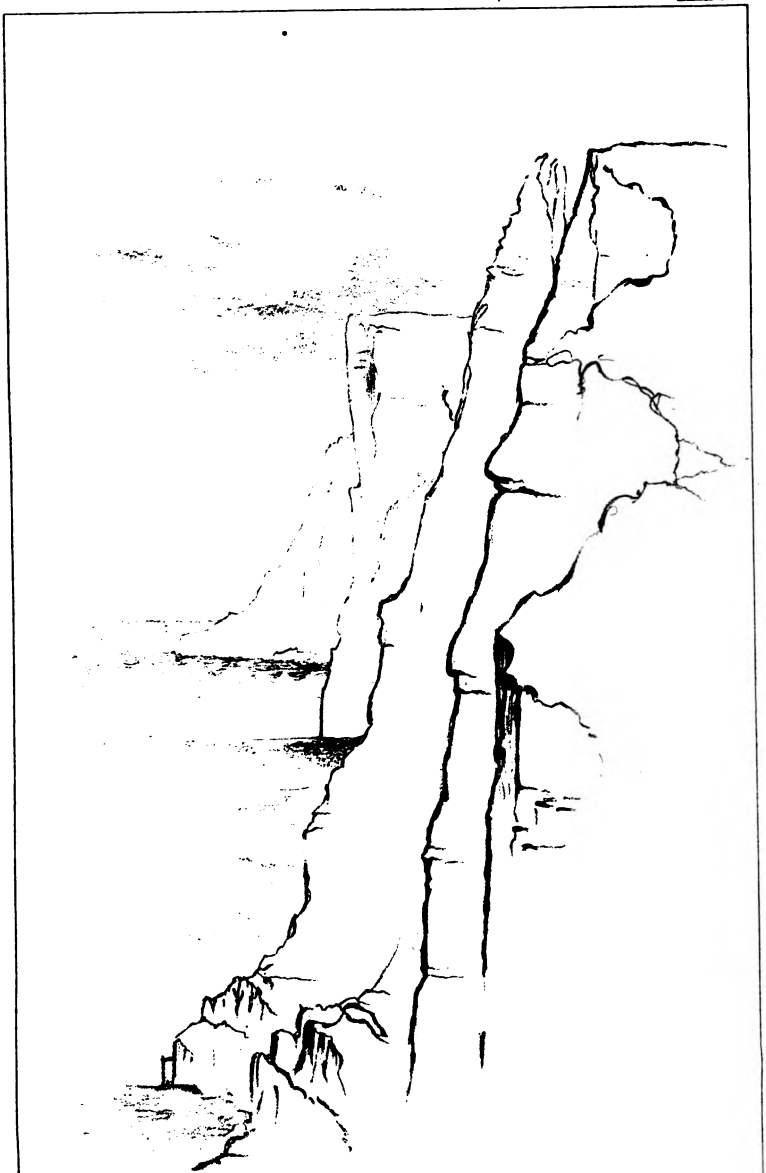

CLO MORE. TORRIDON SANDSTONE.

M. F. H. Del.

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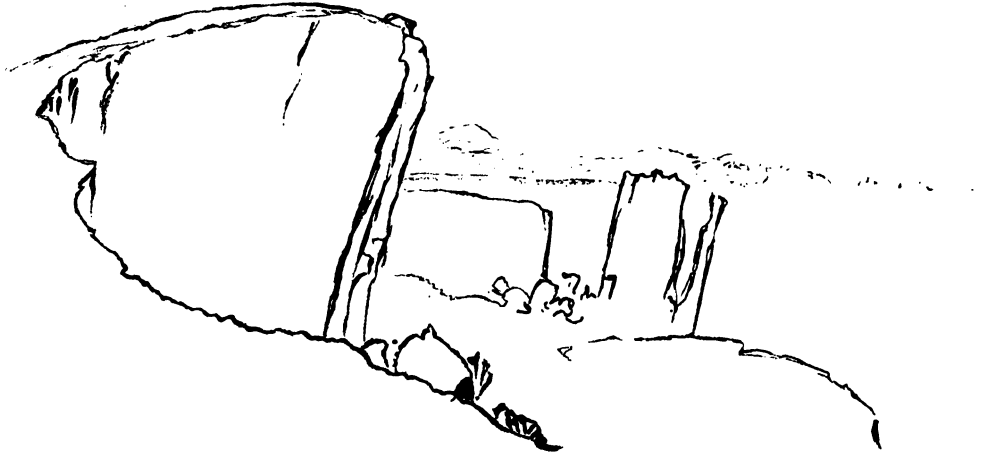

POUL A VOURIN. TORRIDON SANDSTONE.

M.F.H Del

LAKE, TRURO

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the amount of waste which has taken place in what is but a fragment of the past eternity.

The creamy foam, which from the great elevation of these cliffs, is like a white fringe to a russet mantle, seems merely with gentle lavings to be washing the feet of the mighty cliffs;—laving them with with their stockings on, moreover; for mantle of seaweed, and, at a higher level, green swathe of moss intervene, and seem to protect them from the immediate friction of each sweeping surge. But, through swathe and fringe, the ocean is acting instant by instant, and its restless sap is, grain by grain, bearing to its depths the pediments of the mass.

Dr. Macculloch does not hesitate in regarding these as being true sea-cut cliffs; in referring specially to them, he writes—

"The sandstone cliffs are of a grander and more picturesque character than is usual in this rock; from the magnitude of the fracture, and the consequent breadth and boldness of the parts. But they are rendered more striking by the marks of destruction so peculiarly impressed on them; which, while they evince the violence of the wild sea that seems for ever to break along this dreary coast, are in harmony with the aspect of the now unterminated northern ocean.

But in this sandstone, we feel that, in what remains, we can trace what has vanished; the apparent wideness and breadth of the fractured faces reminding us of their recent losses, as if whole cliffs had been carried off and buried in the deep. In a few places indeed, the enormous masses remain pitched on the ledges below where they had fallen; as if the ruin had but just taken place before our eyes."

I have appended a sketch of the spot to which I imagine Dr. Maccullock here refers. It is called Poul a Vourin, and is about three miles south of Sandwood, on the west coast.

Cliffs of the Quartzite and Upper Gneiss.

There is but one Quartzite cliff,—the Whitten Head. This, with its gloomy caverns and pillar-like stacks, is unquestionably grand when contemplated from the ocean level; but from above or in front, it is certainly disappointing. (*See Sketch of Whitten Head.*)

The rock is too enduring to weather into other than rounded form; and indeed there is, in the contour of its terminal summit, a suspicion of ice-action.

Due north of the Head there stand two stacks in close but not absolute juxtaposition. The justice of Macculloch's remarks on the Stack a Cloa is evident on a consideration of these. In height they are not

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much surpassed by the western stack; in similitude of form, and in colour-toning, the spire-like shafts surpass it; but, having no basement-cincture, the resemblance to the Gothic Cathedral is altogether wanting. There is conveyed, instead, a feeling of sameness or of needless repetition; combined, to a certain extent, with that of insecurity; as if they needed somehow to aid each other against the dangers of isolation.

Regarded from this headland, the sombre line of precipices, which, with strongly-contrasted blotchings of green and red, extend for miles across the frontlet of Ben Thutaig, seem to possess outlines of both dignity and grace, which must surpass those of the Whitten. They are uniformly of surpassing altitude, and attain, under Ben Thutaig, a height of 878 feet. The land undulates considerably, probably from alterations in the dip, while the cliff-line is flexured laterally to a considerable amount likewise; so that its verge has the appearance of a cord which is thrown at one and the same moment into two sets of vibrations,—vertical and horizontal. The writer was unfortunately dissuaded from visiting these cliffs, on the ground of distance; but he afterwards found that it would be nothing of a feat, starting from Heilim Inn, to skirt the whole coast-line as far as Melness,—in a long summer day.

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WHITTEN HEAD. QUARTZITE CLIFF.

M.F.H. Del

LAKE, TRURO.

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THE HEBRIDIAN GNEISS.

From among the many names which have been suggested for this formation, I have selected the above, as "it involves no theory, and can contradict no fact."

Laurentian, fundamental, and hornblendic, are all more or less objectionable; and they are so in the order in which they stand.

Laurentian is altogether theoretical; *fundamental* is partially so, and partially assertive; while *hornblendic* is self-assertive.

While it is the case that no rock subjacent to this has yet been found in Britain, there is yet no reason why a lower may not be found. Such a term as *fundamental* should only be applied to the rock which can be proved to be that which is nearest to the earth's centre; and its application should not be confined to one country, but it ought to be reserved for that which is the lowest in any portion of the earth's accessible crust. Nicol puts it well;—"it is a term which in the history of the earth has often proved fallacious. The first has scarce been enthroned before an earlier appears, and in geology it is not the son who dethrones the father—Jupiter, Saturn—but the father who expels the son, to yield in turn to some remoter ancestor. And so it may be here."

Again, as regards the last of the three terms, while it is the case that large, indeed perhaps the largest tracts of this formation are characterised, as regards its composition, by a large content of hornblende, still it has to be noted that extensive tracts do not show that feature,—do not even contain the mineral; while very large tracts of that "upper gneiss" from which it is proposed to distinguish it by the use of the term, do contain the mineral; and, if not in an equally large amount, at least in as markedly a selective manner.

In fact the distinctive feature of the formation as a whole, consists, not in any difference from ordinary gneiss in its component parts, but in a difference in their mode of arrangement, and in their condition. That arrangement may be defined as a markedly *segregatory* one;—the condition has a highly *crystalline* one.

If the extent to which the constituent minerals of a rock-mass have segregated apart, taken along with what may be called their crisp crystalline appearance, be taken as any measure of the amount of metamorphic change which the rock has undergone,—and if the age of the rock-mass be measured by that amount,—then must the

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gneiss of the west coast of Sutherland be unquestionably the oldest of that class of rocks in Scotland.

Composed in its general mass almost solely of pinkish orthoclase felspar, dark-green hornblende, small-flaked black mica, and greasy lustred quartz, it almost nowhere presents anything approaching to a uniform or close-grained mixture of these. Instead of this it shows itself in boldly banded stripes,—the dark mineral, (the hornblende or the mica,) being collected almost totally in certain of these, to the exclusion of the minerals of lighter colour, which consort in others.

Were the rock-layers arranged in anything like a gentle angle to the horizon, this peculiarity could disclose itself only where sea-cliff or ravine-scalp had, by cross-sectioning, laid them bare; but, on account of very high angle to which they have been in most places tilted, this feature of *striped segregation* is almost constantly displayed.

So marked, indeed, is it in some localities,—as along the cliffs a mile south of Cape Wrath, and at Lua Yayi on Loch Erribol,—so sharp the line of demarkation between the hornblendic and the felspathic bands,—and so frequently is there an approach to an actual separation between the layers, that familiarity with the rock alone can avail to disabuse the mind of two false ideas,—first, that these bands define actual layers of deposit,—and, when this error has been expunged, the even graver error, that the felspathic bands are injected granitic dykes.

This last, indeed, they have, by more than one observer, been taken to be.

That they are not so, may be determined by the observation of the following facts:—these felspathic bands invariably run along the strike of the hornblendic beds, never cutting them; and when the beds are flexured, they accommodate themselves to their every fold:—they never bifurcate, or contain any imbedded or floating portions of the hornblendic layers:—their structure, however confused, shews more or less of a laminated arrangement of parts, and nothing whatever of the arrangement special to an injected vein;—and lastly, their mineral composition is not that of an injected vein.

This banded structure, moreover, is possessed of a certain regularity;—the ratio of the bulk of felspathic belting, and the distance of these belts from each other is, in the localities where it is best displayed, a more or less constant one; and the felspathic belting is altogether so great in amount, as beyond measure to surpass any development of injected veins; and even, indeed, the greatest development of the vast system of trap-dykes, the individuals of which, in parallel course, intersect our western shores.

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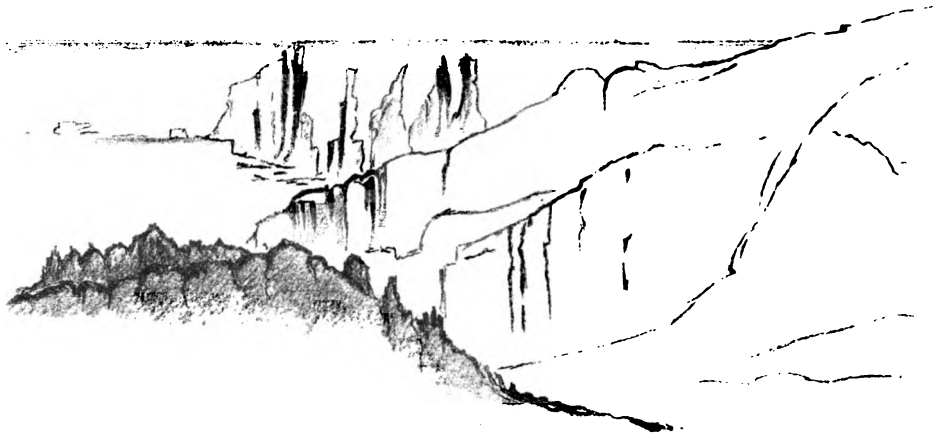

HORNBLENDIC BANDS OF OLD GNEISS, ENDURING AFTER REMOVAL OF FELSPATHIC.
SOUTH OF CAPE RATH.

M F H Del.

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In the south-west reaches of the county, as at Loch Inver and southward to Loch Polly, the dip of the gneiss is not so constant, and by no means at such high angles: here it is much convoluted, and the banding is neither so prevalent, nor are the layers which produce it individually of so large a size. Still, even here, in this minuter if not feebler development of this—the structural characteristic of the rock—the near approach to an actual physical separation of its constituent parts, is a most marked feature. When viewed at some distance, the unconvoluted rock resembles a page ruled for music, while at a nearer distance the convoluted and closer structure resembles a marbled page.

For the individual members of this apparently loose structure, I have elsewhere proposed the term of—*bands of metamorphic segregation.*

It has been said that there is often an approach to an actual separation of the layers of the hornblendic and felspathic bands; if it be actual, there must be lines of weakness; and the beat of waves, or the soak of rain, or the chipping action of blowing sand, may find these out. And this they do sometimes in marked manner.

At a mineral locality, (afterwards to be noted), near Cape Wrath, this rock structure is displayed in its giant development. A tongue of the almost vertically tilted rock receives the full blow of both north-west and south-west waves. These, partly by slapping into the ever-widening chinks, and partly by eating out the more soluble mineral, and doubtless finally by one tremendous finishing stroke, have abstracted many of the felspathic layers, leaving the almost black hornblendic bands to stand erect like isolated basaltic pillars, or the curved and shattered ribs of some gigantic wreck. *(See Sketch).*

At this locality the segregatory force seems to be most highly dominant in the hornblende,—that is, the hornblendic matter displays great power to exclude the silicious and felspathic. Indeed, a little further south, bands of almost pure actinolitic material occur. In general, however, the force seems to draw the two other ingredients into veins apart, though in this case not absolutely apart; for, although these veins contain little or none of the hornblende, still much felspar and quartz remains associated with it, to form the general mass of the rock. This variety of segregation is highly dominant at Lua Yayi. In the *first* locality a pale rock seems banded with black—at the *latter*, a darker-toned rock is lined with zones of a tint much lighter than that of the general mass.

But even when not appearing in this its larger or bolder development, this structure renders the rock a highly characteristic one. With its beds thrown generally at a high tilt, and ground into rounded

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contour almost everywhere by ice, the persistence of the striping-forces itself upon the attention; while that striping is generally so rectilinear as to enable one to determine the strike of the rock, without reference to any face or dip.

While it is more than probable that the felspathic bands of this rock have been mistaken for veins, true veins are also, in some localities, of frequent occurrence;—exhibiting in high perfection their properties of branching, anastomosing, and interlacing.

At the locality where the hornblendic bands are so strongly developed, veins of a granite, which in substance is only remarkable for its small amount of mica, exhibit in great perfection the first two of these properties.

At the spot where, as shown in the sketch, the ribbed hornblende has been robbed of its interstitial felspathic prop, there are no views; but in a cliff directly opposite, dark and light bands are linked together by lacings of granite; and the rock is so strengthened thereby, that here a straight-faced and unbroken sheet is opposed to the lash of the ocean.

In exhibiting the interlacings of granitic-veins, probably no locality in Britain can rival that of Cape Wrath. A drawing of this, taken from the sea-level just beneath the stack west of the Cape, has been given by Dr. Macculloch in the atlas to his "Western Islands."

It has been supposed that this drawing must be an exaggeration.

After lying for a very considerable time endeavouring to unravel some of the less intricate twistings and twinings of the granite,—yea, even of the dishevelled gneissic-layers,—I would, in reference to that drawing, just make use of Dr. Macculloch's own modest words, and say, that while "it is not possible to distinguish always between the pale gneiss and the granite, the truth of the essential parts of the drawing has remained untouched."

He who would unravel the mystery of granite veins, has much to unravel here, and anyone who attempts this mystery should study long, at this spot. There is one conlusion which cannot but soon impress itself upon him in the so-doing;—namely, that the granite was infused into the rents *at no very elevated temperature*. The ramifications dwindle away to the thickness, or the thinness rather, of the edge of a knife. No molten matter could remain fluent in so narrow a crevice of a *cold* mould. In making minute castings, even in so easily liquifiable a metal as pewter, the mould is heated;—or again, as in the case of the marvellously delicate ornaments which were made when the patriotic German ladies "gave gold for iron." But it will hardly be

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ged that the mould was in the present case heated up to near the elting point of granite; and in sooth it would prove far from easy to bstantiate any great augmentation. Truly it is becoming necessary at geologists should tone down their temperatures.

In addition to the pale granite of the veins as usually seen in this ›cality, there is a second variety of a fiery-red colour, with imbedded ɔaque white quartz, but no mica. I have not observed these to ɹmify to any great extent.

Perchance of the many difficulties connected with granite veins, there ɜ none greater than the singular manner in which the terminations of ɔoped branchings cut the stem from which they started. This they do requently within a very short space of their point of branching.

The cutting or self-rending, as the case may be, of a distinctly aminated rock by curvilinear rents is itself an enigma; but the fact of ɔne portion of a vein having become so solid as to be capable of being rent, while it was still exuding the material which plugged that rent, is a very much greater enigma.

At a small quarry to which a cart-track leads, just about the summit of the rising ground behind the lighthouse, there occurs an appearance in the granitic veins which neither the writer nor, he believes, his companion Professor Geikie, had before observed.

The quarrying operations have here cut through a small outlier of the Conglomerate, and exposed a face of the gneiss, with undulating convolutions,—well marked by the dark and light bands of the stone. Branching granite veins, of from a foot to three or four inches in thickness, ramify through this, *at right angles to the zonings*. We were perplexed by observing not mere indications, but, in several of these veins, both in the main trunk and in the branches, a fairly-well pronounced development of structure within the veins themselves. This structure was *accordant with that of the banded gneiss*. That is to say,—in a precisely similar manner as the micaceous or hornblendic material of the gneiss was disposed in continuous bands, there was an arrangement in the granite vein of the dark mica which it contained. And this arrangement of the mica of the vein was disposed *in immediate continuation of the zoning of the gneiss*. It was far from as distinct, because there was not in the granite nearly as much mica as there was of the two dark minerals in the gneiss; but, so far as its mica went, it was as absolutely confined to the lines which passed more or less across the vein, *in continuation of those in the gneiss*.

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A zoning or banding of granite veins *parallel* to the sides of *the vein* is not uncommon; but one *transverse to it*, and synchronous with the structure of the rock which the veins cut, is perhaps now first noticed.

The impression at first sight conveyed, was one which can hardly be for a moment entertained; it was that the zoned structure of the gneiss had been impressed upon it, *after* it had been cut by the veins, and that the linear arrangement of particles had affected both simultaneously.

This gneissic formation has a prevailing N.W. and S.E. strike; and, in Sutherland at least, it has a prevalent high dip to S.W.; but this is not without exception. At Cape Wrath it dips to the south-east, and with a much lower dip; while in the south-west of the county, the dip, though in the usual direction, is also a lower one; while there occur there, though only on a small scale, undulating folds.

It is in those parts of the county where the strike and dip departs from the ordinary, that the rock exhibits the most extensive convolutions.

A wonderfully fine illustration of contorted structure is displayed upon a rock-face immediately west of and beneath the light-house at the Cape.

The cliff-face is here formed by a strike-joint; and a smooth face of rock, nearly 90 feet wide by about 150 high, exhibits on its surface, drawn in the boldest character, both ample and minutely-crumpled foldings. These sweep from side to side in a repeated sequence of dark-green lines. It is altogether on so prodigious a scale, and so fair-fronted to the ocean, that it looks like a huge diagram displayed to passing ships.

Besides the three most usual ingredients of this gneiss, and the less frequent mica, the rock contains a substance which occurs in some districts in such quantity, that it has every claim to be itself regarded as a constituent. This substance was first noticed by Dr. Macculloch, and noted by him as occurring in Iona,—the first of the gneiss islands which he described. He thus speaks of it.

"One peculiarity attends all these rocks, namely, the great abundance of a substance hitherto considered as compact epidote, which is everywhere found in them.

"It forms either large lumps or laminæ imbedded in the gneiss; and in some situations enters into it as a constituent part. In other places

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it is found mixed with hornblende in various ways, or else serving for a base in which crystals of hornblende are imbedded; *forming a rock which has been mistaken for serpentine.**

"As this substance does not seem to be very common, and seems to have in a great measure escaped attention, a description of its prominent characters will not be superfluous.

"It is generally pale-green, at times approaching to yellow. The fracture is intermediate between the conchoidal and the flat-splintery, and it is exceedingly difficult to break; the fragments are slightly translucent on the edges. It does not easily yield to the file, and scratches quartz; while in return it is scratched by that substance. Its specific gravity is the same as that of quartz, but it has not been analysed. From a comparison of the characters of numerous specimens, selected from different parts, I am inclined to consider it as a variety of compact felspar, and it will indeed be found to pass into the more common varieties of that substance. It forms a conspicuous portion of a gneiss abounding on the west coast of Rosshire."

It is the last statement of Dr. Macculloch, no less than the very close agreement in characters, that enables me to conclude that this is the substance to which I refer. The latter occurs in greater quantity, and perhaps in a purer state in the west of Rosshire, than at any other spot where I have observed it. I have broken out veins of over an inch in thickness in the neighbourhood of Poolewe.

As I did not come to the same conclusion as Dr. Macculloch, as to the nature of this substance, I have made several attempts to procure specimens pure enough for analysis,—not only on account of the desirableness of ascertaining the nature of a doubtful substance, but more especially from the fact that, as this substance occurs very frequently in certain parts of the "igneous rock," which is found in a very interesting line of country, a knowledge of its composition is absolutely called for.

Up to the present time all my attempts at obtaining an unmixed result from my picking, have failed,—not so much from an admixture of hornblende and felspar, as noted by Macculloch, but of quartz.

I have gone so far, however, as to be able to say that there are the strongest chemical, as well as mineralogical reasons, for doubting this being a felspar.

* The italics are the writer's, not Dr. Macculloch's.

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Many of the Loch Maree specimens seem to show an incipient crystallisation of the green matter, which runs into opaline quartz. I conclude that the thing as a whole is that *mélange* which has been termed *epidosite*; and the occurrence in Harris of thin veins of crystallised epidote, with distinct and separate minute crystals of quartz, goes so far in negativing the conclusion that it is a felspar. I shall, therefore, with a *caveat*, term it meanwhile *epidosite*.

Garnet is mentioned by Macculloch and others as occurring in this gneiss; and my confrere Mr. Dudgeon and I found it in one locality in union with hornblende and kyanite, in such preponderating and enormous quantity, that there it was almost a garnet-rock, (eklogite) and it prepared us for meeting with it anywhere in the formation.

Where convolutions occur in the gneiss they throw the flexures of the hornblendic bands into protrusions, well seen on denuded or sea-scalped surfaces. This frequently leads to the impression that these protrusions are imbedded crystalline nodules, or kernels of the mineral, —such as would result from a concretionary structure. It requires some care to be able in all cases to undeceive oneself as to this; the more especially as isolated arrangements of crystals, or subfibrous masses of hornblende of kernel-like appearance, *are* to be found in this gneiss,—as at the Island of Ensay in the sound of Harris, and, as stated by Murchison and Nicol, at Loch Inver.

Nicol mentions such as occurring of a light-green colour, near Loch Inver, up to two feet in size.

Moreover, wherever there is any great amount of puckering, and so of local amplification of the thickness of the hornblendic layers, the crystalline force, having an unusually large amount of matter to operate upon, asserts itself with more than usual success; and at such points, there are even to be found rudely-formed crystals or crystalline masses;—a foliated arrangement of particles being here altogether lost.

An extraordinary, indeed an altogether unique illustration of several of the above structural developments, is to be seen among the cliffs at Rhu Craig-a-Vail,—the north-western promontory of the Bay of Scourie.

At this spot the gneiss, which is of a somewhat more thinly-banded structure, with perhaps less separation of its several ingredients than usually obtains, is thrown into highly intricate and tortuous convolutions. The domed summit of an extraordinarily plicated protrusion-fold has been denuded off, partly by marine breaching, partly it would appear

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by actual quarrying,—(for the purpose, probably, of more thoroughly exposing the very peculiar manner in which the dark hornblendic layers are crumpled up.) It exhibits in section a singularly-close resemblance to a huge soup-ladle.

At the periphery of the bowl of the ladle, the darker layers of the rock are folded upon and within themselves to an extent that is not surpassed by the convolutions of the brain, or the intricate structure of the tooth of the labyrinthodon. It is a most extraordinary and extreme illustration of the pliability of solid or semi-solid matter under the exercise of enormous force.

From among the so-called hornblendic layers which are thus contorted, there is to be obtained the rare mineral *hydrous anthophyllite* —(D.) Its mode or state of occurrence is most interesting.

In chiselling off portions of the crystalline layers, the tool suddenly sank into an underlying pulpy mud or clay, of a fawn-yellow colour. This was perfectly plastic, soiling the hands and clothes; it was, even upon its first exposure, however, seen to contain spiculæ of a crystalline matter.

This damp substance rapidly hardened; it could next day be broken, though with difficulty, from its retaining somewhat of its plasticity. In the course of some months it constituted an easily crumbled stone, and ultimately hardened to the ordinary consistence of rock,—having all the appearance of a pale *hydrous-anthophyllite.*

As mineral specimens they now appear as a confused arrangement of minute acicular crystals; their colour is now pale olive-green; their lustre between pearly and greasy.

Some specimens contain small crystals of *talc* or *ripidolite,* of the same colour:

When reduced to powder, the colour rapidly changes to that of chocolate.

The specific gravity is 2·917.

The analysis is afforded—

Silica	45·508
Alumina	6·588
Ferrous Oxide	14·285
Lime	4·437
Magnesia	22·14
Alkalies	traces.
Water	6·721
	99·479 (H.)

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The change of colour above noticed as occurring during the pulverisation is very peculiar. I shall have to notice this as occurring not unfrequently in the same circumstances. *It is not the result of peroxidation during the great surface-exposure which results from the process of comminution;* that this is the case, is in the above analysis shewn by the total absence of Ferric-oxide.

It probably is due to the change in the *form* of the particles being attended by some modification in their action upon light. Something of this very kind was shewn by Brewster to be the cause of the change of colour in chlorophæite. In this latter mineral it occurs upon mere exposure, and without actual interference; and is found to result from shrinkage-cracking, due to partial dehydration. I find this change is in all case *expedited* by pulverising; and I am inclined to believe that a similar though very inferior amount of the same change, which is to be seen to occur in many *saponites*, is due either to the same cause, or to their containing small quantities of *chlorophæite* in intimate intermixture.

The darker crystals which at this spot inclosed the orginally pulpy material, may be actinolite; but they more probably are themselves hydrous-anthophyllite, darkened through exposure;—they are dark-green and brittle.

While perhaps the nearest approach to independent crystallisations of hornblende are to be seen upon the slopes of Foinaven, the locality where the greatest amount of hornblendic matter segregating apart occurs, is upon the north-east foot of the hill of Kean-na-Bin, near to the branching of the shore-road to Rispond.

Here masses of *hornblende*, consisting of radiating and interlacing brushes of crystals of a somewhat actinolitic type, are to be seen, of a foot or two in bulk.

The colour is a dark but brilliant grass-green; the lustre is high; and, as the interlacing crystals are some inches in length, and the specimens can be split into thin slabs, they form one of the finest varieties of the mineral to be procured in Scotland.

Small brilliant crystals of *pyrites*, of the form *a o*, are lodged among the fibres, exalting their effect as specimens; and a small quantity of a mineral, which may be *grastite*, occurs as a thin coating, rarely.

It has been said that the ordinary constituents of this gneiss are orthoclase, quartz, and hornblende; the two former being frequently to a great extent associated apart in bands,—in these *oligoclase* is of rare occurrence. Towards the north-eastern limits of the rock, as along the western shore of Loch Erribol, at Lua Yayi, and Kean-na Bin, these ingredients seem to be undergoing alteration; the orthoclase being of

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a heightened red-colour, a greasy lustre, and of markedly less than the normal hardness. Little quartz here occurs, and large lumps of massive pea-green *agalmatolite* (D. and H.) surround the crystalline masses of the felspar; this agalmatolite has probably resulted from a change of the oligoclase.

Our knowledge of *rock-alteration* being altogether scanty, both of the above substances were analysed.

The *orthoclase*, as above noted, was of an unusually-bright flesh colour; its specific gravity was 2·554; it was powdered with very unusual ease. It yielded,—

Silica	63·846
Alumina	18·489
Ferric Oxide	1·318
Manganous Oxide	·115
Lime	·43
Magnesia	·769
Potash	13·021
Soda	·919
Water	·393
	99·8 (H.)

The magnesia is here but slightly in excess of the quantity usually present.

The *agalmatolite* was first found in imbedded massive patches in granite, in a dyke near the village of Kean na Bin. It was traced to the cliffs opposite the island of Koilskeir; and, until it was analysed, it was ticketted "indurated steatite,"—with a mark of doubt.

Being in larger masses at Lua Yayi, specimens from this last locality were chosen for analysis. At both localities the mineral is fine-granular, and has a greasy lustre. It cuts like slate-pencil. Its specific gravity is 2·77. It absorbs ·7 per cent. of moisture.

Its analysis yielded—

Silica	48·723
Alumina	31·56
Ferric Oxide	2·43
Magnesia	1·809
Potash	9·485
Soda	·312
Water	5·752
	100·086 (H.)

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It is many years since Dr. Macculloch threw out the conjecture that "indurated steatite" was of the nature of agalmatolite. Of several substances which might lay claim to such a name as *indurated* steatite, this is perhaps that which most deserves it; the above analysis shows the nature of the substance for the first time, and probably first proves *agalmatolite* to be British. The definite information thus obtained enables us to recognize as the same mineral, certain hitherto doubtful green masses which occur elsewhere, imbedded in granitic rocks. This substance and its probable mode of formation was also noticed by Cunninghame, who writes—"Near the village of Rispond, the gneiss makes a transition into a rock composed of large concretions of serpentine and quartz, between the two there being also every mode of gradation."

Cunninghame's "serpentine" is the agalmatolite.

While I have to admit that it is mere conjecture—(indeed, the vaguest conjecture, seeing that pieces of oligoclase equally large are rarely to be seen in these felspathic belts)—which assigns the occurrence of this mineral to a change of *oligoclase*, I have to say that I have not infrequently seen *orthoclase passing, on its exposed surfaces, into a substance not to be distinguished from this.*

I instance the orthoclase of an intrusive dyke at Geo na Shermaig, —of an exfiltration-vein at Knock Dhu near Lairg,—and of probably a similar vein in the red granite near Murdoch's Head quarry, in Aberdeenshire.

Of the ordinary constituents of this gneiss,—if they be of *this* gneiss, which is doubtful,—two other, somewhat unusual-looking varieties, were analysed. These were both found in one large mass which lay on the east shore of the Kyle of Duirness, somewhat below the Ferry.

The original locality of this mass, or of a perfectly similar rock, was found to be the north-west slopes of Ben Spinnu, at a height of about five hundred feet. (H.) Here the rock is well-displayed in cross-section, in the beds of several burns. It is a hornblendic gneiss, but the dip here is to the north-east, and at an angle of only from 20 to 32 degrees.

The rock is of a more laminated, and a less markedly banded character than is usual in the "lower gneiss"; and I much incline to believe it to be a portion of a bed of rock belonging to an altogether different age, which, like the limestone of Duirness, has been let-down by a great fault.

The felspathic layers here are less well-marked, they do not maintain any regularity in their width, and they are frequently plicated.

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The *orthoclase* is saccharoid in structure, of a yellowish-pink colour, a high glancing lustre—very like a granular marble, and it is very unlike ordinary orthoclase. It contains imbedded crystals of the substance immediately to be noticed, along with rare crystals of pale-brown resinous *sphene*.

Its analysis yielded—

Silica	64·153
Alumina	19·066
Ferric Oxide	1·318
Manganous Oxide	·538
Lime	·947
Magnesia	·384
Potash	11·166
Soda	1·749
Water	·714
	100·035 (H.)

The crystals imbedded in this felspar are probably *uralite* (H.) They are of about half-an-inch in size, of a rich dark-green colour; —they show well the *c* cleavage of augite, but to the goniometer give cleavage-angles of both augite and hornblende. They are unusually hard for *either* of the last-named minerals.

The analysis yielded—

Silica	51·461
Alumina	2·968
Ferric Oxide	2·451
Ferrous Oxide	9·661
Manganous Oxide	1·076
Lime	20·073
Magnesia	10·461
Potash	·683
Soda	1·305
Water	·683
	100·827 (H.)

Thus agreeing in composition with *augite*. The structure, however, would appear to be that of *uralite;* and this combination of augite and hornblende I have never seen in any locality in which the gneiss was unmistakably the *lowest lying rock*. In *it* the mineral is invariably ordinary laminated-hornblende, seldom concreting into large crystalline masses, and then only where close-folding of the rock throws together an unusually large quantity of the mineral. The most distinctly crystalline masses of such hornblende are to be seen in the neighbourhood

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of Loch Inver, and on the western slopes of Foinaven; and at neither of these localities have I seen crystals of half the dimensions of this *uralite*.

Rarely the hornblende is not of the platy variety, but *actinolitic*: broad bands of this variety, almost simulating veins, are to be seen among the western cliffs, about two miles south of Cape Wrath.

Of accessory minerals this gneiss carries but few in its general substance; and the few that I have seen occur chiefly at the locality last mentioned.

At this grandly picturesque headland, the hornblendic gneiss of the west coast differs in its features very considerably from those which elsewhere may be said to be almost unvarying. The dip here is low, and to the east or east-south-east; it is highly corrugated and folded, and it is rent, and shifted, and reagglutinated by an anastomosing and mutually-intersecting series of granitic veins. Its own granitic belts, instead of assuming, as elsewhere, much of the character of a set of parallel dykes with abrupt and sharply-marked surfaces, blend by insensible gradation into the ordinary material of the rock, which is here even somewhat of the nature of granite itself.

It is this greater consistency of the rock as a whole, this more intimate interpenetration and consequent firmer cohesion of its parts, coupled with the altogether unique manner in which its every layer is bound together by granitic cords of unusual toughness, (interlaced in such a manner as to defy unravelling,) that it has formed, and must for long form so fitting a termination to a kingdom,—so enduring a rampart against even Atlantic billows.

Such are the features of the rock for about a mile to east and south of the lighthouse; another, however, has to be noticed,—it is, within the space so included, much less characterised by the presence of particles of hornblende than is usual; being of a pinkish, instead of a green cast of colour. This local deficiency of hornblende is, however, suddenly more than compensated for, about one and a half miles south of the lighthouse; here the strata have gradually increased their dip, and assumed the line of outcrop, which is normal to the rock in the south. The beds are here almost alternatingly hornblendic and felspathic; and—as the intermediate felspathic bands have frequently yielded to the weather,—the former stand erect in repeated sequence, simulating dykes of a dark igneous rock.

Just about the same spot, also, in cove-like recesses of the older-rock, the horizontal strata of that many-coloured conglomerate which has been assigned to the Cambrian epoch, makes its appearance, in outlying portions of very circumscribed dimensions.

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In the second (to the south) of these coves of the Cambrian sea,--one which is now sentinelled to the north by a grand development of the black bands of the older rock, and on the south by an equally grand illustration of intrusively anastomosing granite,—my companion Professor Geikie and I hit upon an interesting mineral locality.

It is situated on the grassy bank, only some few feet below where the conglomerate reposes in peacefully rectilinear beds upon the denuded gneiss, which here dips from the under-surface of these beds almost at right angles.

The first of these erected beds to which interest attaches, carries a *jaspery chert* with yellow *moss-agate*; in association with this *hydrous anthophyllite* (Geikie and H.) is to be seen. It has taken the form of concreted nodules consisting of bundles of radiating fibres. The mineral here is greenish-brown in colour, occasionally showing the bronzy-brown of true anthophyllite.

An ill-defined substance resembling fibrous *Wollastonite* also occurs.

The more southerly of the veins is, for the most part, a light-green fibrous-*actynolite*; but it also carries *ripidolite* and *steatite*. (G. and H.)

The *ripidolite* forms belts in the rock; these belts here consist of foliaceous masses of nearly parallel scales about the size of peas; these have a greasy lustre, and a blackish-green colour. Its specific gravity is 2·823.

It yielded,—

Silica	31·034
Alumina	14·845
Ferric Oxide	5·73
Ferrous Oxide	17·417
Manganous Oxide	·998
Lime	·355
Magnesia	17·422
Water	12·481
	100·292 (H.)

A year after our discovery of this mineral locality, the present writer found two others which lie in similar recesses among the rocks some little distance to the south. These contain the ripidolite in much larger quantity, but here its only associate is actinolitic hornblende.

The *steatite* forms a thin vein in the actinolite of about an inch in thickness; it is unusually dense in structure, appearing to be fine-granular. Its colour varies from slate-blue to lavender. Its specific gravity is 2·797.

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Its analysis yielded—

Silica	59·108
Alumina	·463
Ferric Oxide	2·65
Ferrous Oxide	3·251
Manganous Oxide	·23
Lime	·43
Magnesia	28·67
Water	5·164
	99·966 (H.)

A thin vein of *chalcopyrite* with *chrysocolla* was found in the gneiss to the south-east of Rhiconich (D and H.); this was traced eastward up the west shoulder of Foinaven to a height of about 700 feet, but it gradually thinned off. In its neighbourhood at the latter locality are to be found specimens of *micaceous-iron*. (H.)

An isolated mass of the gneiss which lies to the north of Sandwood, contains minute grains of *iserine* (H.): this is to be seen in large quantity in the form of a black sand, which lies on the surface of a dangerous quicksand, between the lake of Sandwood and the Atlantic.

A very small quantity of this sand is magnetic, and doubtless is *magnetite*; the non-magnetic portion yielded:—

Titanic Acid	10·6
Alumina	·072
Ferric Oxide	80·876
Ferrous Oxide	5·961
Manganous Oxide	·4
Lime	·952
Silica	1·5
	100·361 (H.)

Murchison notes that in a little burn adjacent to the Ferry House on the west-side of the Kyle of Duirness, the rock is charged with *asbestus* and *actinolite*. About a fourth of a mile north of this house, a flaggy hornblende rock yields platy *hornblende*. (H.)

The not infrequent approach to an actual separation between the felspathic bands and the hornblendic laminæ of the gneiss,—amounting occasionally to a looseness of structure,—conjoined with the manner in which the high dip lays bare to the air the denuded edges of the strata, expose this rock very directly to the assaults of the various agents and forces which effect disintegration. It accordingly occasionally presents scenes of ruin and waste. On the coast line south of Cape Wrath, the more soluble felspathic portions have been sapped out so that the dark hornblendic layers frequently stand isolated like enduring dykes.

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In compensation, as it were, of the weakness thus induced, its layers are very generally laced and bound together by granitic dykes,—occasionally straight in their course and independent, but much more frequently anastomosing with each other, and tortuous in the extreme.

The components of these intrusive granitic dykes, whether they be rectilinear or tortuous in their course, are very similar; but they differ from those of the felspathic bands of the gneiss, in the following particulars. The ampler size of each of the several constituents,—the invariable presence of oligoclase,—and the very frequent presence of the new black mica, which the writer has called *Haughtonite*.

Nowhere perhaps are those dykes which maintain a straight course seen in ampler development, or with their several constituents exhibiting larger crystals, than in the west spur of Foinaven.

The *orthoclase*, here in crystals the size of the fist, is of a translucent pink or flesh colour. It exhibits that peculiarity of structure which I will fully describe as occurring in the amazonstone of Ben Bhreck; but here the structure is on so large a scale as to be palpable to the naked eye, even at some little distance,—instead of calling for the aid of a pocket lens. The specific gravity of this orthoclase is 2·565.

The *oligoclase*, in crystals of a magnitude nearly equalling the orthoclase, is of a snow-white colour, and is beautifully striated. Its specific gravity is 2·634. P.*

Among these specimens I found a piece or two of *Sonnenstein*, which I do not remember to have seen previously noted as British. The inclosed scales of rubin-glimmer are disposed for the most part parallel to the face *c*; and (as is also the case in perthite) they do not occur in the albitic or oligoclastic portions.

The *Haughtonite* (H.) occurs rarely. It is in crystalline foliæ of nearly an inch in size, of a velvety blackness, and of an exceedingly high lustre. Its specific gravity is 3·032.

Its composition is

Silica	36·75
Alumina	17·858
Ferric Oxide	2·781
Ferrous Oxide	15·175
Manganous Oxide	·416
Lime	·933
Magnesia	11·166
Potash	9·437
Soda	1·247
Water	4·232
	99·995 (H.)

* Analysis deferred (though material prepared) wherever P. attached.

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The finest specimens occur at a height of about 750 feet; and here the mineral seems to be in hexagonal crystals.

Much larger plates of the same mica were found in a granitic mass, which lay upon the side of the road on the south shore of Loch Stack. (D. Jo. and H) This mass appeared to have fallen from the cliffs which skirt this side of the hill; but whether it was from an intrusion vein or not, could not be ascertained; the block had the appearance of such. The mica was in plates some inches in size. These plates had much less lustre than those from Foinaven; they were of a brownish-black colour, becoming green on being crushed.

Their composition was

Silica	35·692
Alumina	20·086
Ferric Oxide	2·233
Ferrous Oxide	14·011
Manganous Oxide	1·
Lime	1·895
Magnesia	14·769
Potash	7·381
Soda	·529
Water	2·465
	100·058 (H.)

This mineral, from the large quantity of ferrous oxide which it contains, is somewhat prone to decomposition. In some localities this is indicated by the assumption of a green, and ultimately of a pale-green colour

In Sutherland and in Harris, however, it becomes brown or reddish brown, and opaque; exfoliating much, and softening at the same time.

A good illustration of this change is to be seen in a vein which occurs in the cliffs immediately after rounding the small promontory which lies to the south of the ripidolite locality, near Cape Wrath. (G. and H.)

This vein, which consists chiefly of *oligoclase*, is much decomposed and loosened in structure,—falling to pieces readily before the pick. Quantities of crystals of *Haughtonite* occur in it.

These, on their edges, are red, opaque, and palpably decomposed.

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Their *apparently unaltered* centres yielded—

Silica	34·153
Alumina	14·837
Ferric Oxide	10·961
Ferrous Oxide	13·474
Manganous Oxide	1·384
Lime	1·809
Magnesia	10·307
Potash	7·93
Soda	2·136
Water	2·8
	99·791 (H.)

The centres even of these crystals, then, though they were of some size and of a dark-brown colour, may be held to be peroxidised; and it is probable that the disintegration of the vein is due to this absorption of oxygen, and consequent expansion or exfoliation.

Even where this mineral is absent, these veins may, in exposed localities, suffer change from an alteration in the *felspars* which they contain.

In the steep overhanging bank which skirts the south-east side of the Geo na Shermaig near Cape Wrath, both the orthoclase, (here fiery red), and the oligoclase, have an appearance which indicates incipient change,—namely, a certain amount of a greasy opacity of lustre.

The *orthoclase* had a specific gravity of 2·563. P.

In the case of the *oligoclase*, it could be observed that, besides its having a fatty lustre, the usual striation was very feebly marked, and that the colour was a dirty, instead of a pure watery-white.

Its specific gravity was 2·654 and it yielded—

Silica	64·538
Alumina	24·039
Ferric Oxide	2·307
Lime	1·206
Magnesia	·769
Potash	2·586
Soda	4·133
Water	·843
	100·421 (H.)

Here there is a decided loss of alkalies, and some loss also of the lime; no marked increment—certainly no *intrusion*—of magnesia is noticeable.

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Of intrusive dykes differing from the types above noticed, Sutherland does not supply many varieties.

Along the north shore of Loch Assynt the gneiss in some few spots assumes, through weathering, an appearance very similar to that of an igneous rock; and at one of these localities, some four miles from the foot of the lake, I could not assure myself that it was not of that nature. It exhibited an appearance upon decomposition, strikingly like that of onion-basalt; but unfortunately at the locality it could not be seen whether there was any junction with a gneiss of ordinary appearance.

On the north shore of a small lake, which lies between Quinaig and Unapol, there are some dykes (?) of massive *white quartz*, strikingly auriferous in appearance. A little westward of Scoorie, a pale-green much-fissured *vitreous quartz* occurs in dykes with a northerly strike. This quartz much resembles olivine; its specific gravity however proved its nature.

The most interesting dyke which occurs in this gneiss, is that which occurs in the north shore of the little harbour of Rispond.

This is composed for the most part of *graphic granite*, the felspar of which is red. From the close arrangement of the skeleton quartz crystals, and the sharpness of their angles when cut in cross-section, this is the finest graphic granite of a red hue now to be got in Scotland; (the once famous locality,—at Portsoy,—no longer yielding any specimens of value). The felspar of this pegmatite has a fine nacreous lustre; and sections of the rock form an interesting object for the polarising microscope; as the "corded-structure," previously noticed, is finely displayed, and is pleasingly diversified by the interrupting quartz

This dyke also yields masses and crystals of *oligoclase*, over the size of the fist;—these are highly lustrous, white or colourless, and translucent; they are finely striated; their specific gravity is 2·636, and their cleavage angle 86° 14′.

Their analysis yielded :—

Silica	61·848
Alumina	21·703
Ferric Oxic	3·37
Manganous Oxide..	·196
Manganese	·09
Lime	4·129
Potash	1·63
Soda	6·952
Water	·375
	100·293 (H.)

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From the fine development of the striation of this oligoclase, its large character, and the purity of the specimens, this may be regarded as the best locality for the mineral in Scotland. The Rispond vein also carries *Haughtonite* of two appearances, and *magnetite*. (D. & H.) The three minerals occur in nearly equal amounts.

The usual appearance of the Haughtonite is in jet-black highly lustrous crystals, which show traces of a hexagonal form.

Having blasted the rock to some extent, in order to obtain masses of the graphic granite, sufficiently large for being formed into platters, I also, from its deeper-seated portions, procured the same mica in large plates, of a dull and somewhat greasy lustre;—the colour of these was brown. This induces the conjecture that in some cases the high lustre and greater depth of colour may be the result of exposure.

The black variety has a specific gravity of 2·99; it yielded:—

Silica	36·538
Alumina	22·282
Ferric Oxide	2·433
Ferrous Oxide	16·009
Manganeus Oxide	·784
Lime	1·249
Magnesia	10·
Potash	8·264
Soda	·794
Water	1·506
	99·856 (H.)

The *magnetite* occurs rarely in tetrahedral crystals with octahedral truncations; it is usually however in imbedded masses, up to half the size of the fist. These are extremely solid, appearing to be rough crystals,—fine flat cleavages always running through their whole extent. It is the finest massive magnetite of Scotland. The colour is blue-black, becoming brownish when powdered. Its specific gravity is 5·15.

Its analysis yielded,—P.

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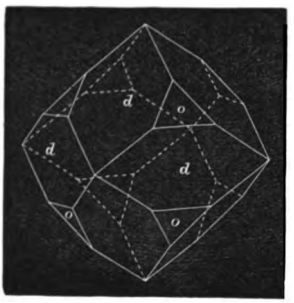

Nearer to Kean na Bin and opposite to the west end of Hoan Island, smaller granite veins of brick-red *orthoclase*, with beautifully striated crystals of *oligoclase*, also carry *magnetite*; it is here in octahedral, frequently in rhombic-dodecahedral crystals, with octahedral facets; though it is for the most part massive. Its colour is brownish-black, and it has little lustre.

Its analysis yielded :—

Ferric Oxide	89·632
Ferrous Oxide	4·241
Manganous Oxide..	·3
Lime	2·688
Magnesia	·9
Silica	1·9
Titanic Acid	·5
	100·161 (H.)

Having thus passed almost totally into *martite*.

The Conglomerates and Grits.

Overlying the well-marked and highly characteristic hornblendic rock, there rests in the most complete discordance therewith, a deposit of great thickness. This consists of beds which from bottom to top are characterised by the features which pertain to a ruin, without having any of the new or characteristic features which are essential to a new structure.

Of such a mass it may be possible to say from what, or whence it came; but, it palpably cannot bear much internal evidence as to *when* it was deposited.

External evidence may warrant its being *assigned* in age to a certain formation, if it is generally admitted that the evidence is clear, and if the inferences to be drawn therefrom be indisputable. Beyond or aside of this, all must stand as speculation.

Sir Rhoderick Murchison asserts that "these conglomerates are made up exclusively of the gneiss upon which they rest."

To this the writer must demur. While he is not in a position to deny that this many-bedded formation is in some part formed of the ruins of the underlying gneiss, yet there are two facts connected with its main bulk which are not altogether easy of explanation.

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The first of these difficulties is the total, or almost total absence of hornblende in its substance, or among its rounded fragments.

The great prevalence of hornblende in the lower rock has been noted. To emphasise this. the following quotations from Murchison may suffice.

"The body of the rock is usually hornblendic. In ascending from the village of Loch Inver to Dunn Swordalan, the groves and veins of hornblende are so rife as to constitute the chief mass of the rock."

"Whether it be examined at Cape Wrath or at any point southward to Loch Inver, it has everywhere the same grey hornblendic basis."

Now, putting meanwhile out of consideration a fundamental *breccia*, the writer, who has examined the conglomerate carefully from the far north Scrishven to the flaggy beds in Rum, for the very purpose of detecting this mineral, never was able to find among its attrited portions either chip or mud of hornblende. He had also no difficulty in showing that what was in an isolated case pointed out to him as that mineral, was an earthy substance resembling granular chlorite.

Long ago Dr. Maculloch made the same observation. He writes.—"In no instance have I observed it to contain mica, nor, with the exception of red *jasper*, and that of the schist just mentioned, any substances but quartz and felspar."

As further evidence which bears upon this point, we will quote Cunninghame, who commences his description by saying "The red conglomerate is composed of variously sized and rounded fragments of massive quartz, *red jasper*, and common felspar, held together by a basis of the same. Mica occurs in minute scales, but is not abundant." Nowhere in his description does he mention the hornblende, though it is repeatedly noticed in his previous description of the gneiss.

Nicol says—"Throughout the whole of this range, the red sandstone is very uniform in aspect and mineral character. Most of it is a rather coarse grit, with fragments rarely an inch or more in diameter. The fragments are not much water-worn, and consist especially of quartz, *hornstone*, and felspar, the latter often decomposed. The grits are composed chiefly of rounded grains of grey vitreous quartz and red felspar, but apparently no mica." "The quartz is white and vitreous, or red ferruginous, or a kind of *blue hornstone*."

Professor Bonney lately writes—"I am not able to detect any indubitably fragmental mica or hornblende, and must be content to call the green mineral which is sparingly present in the matrix, and which is almost certainly a secondary product, by the vague term viridite."

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In fact, neither can the lens-aided eye in the conglomerate, nor the microscope in slices of the fine-grained sandstones, find this substance.

That a finely comminuted hornblendic mud should have been held in suspension long after solid pebbles of quartz and felspar had settled to the bottom, would but be in accordance with the normal process of rock formation; but that no single crystal, chip, or unbroken pebble of the enormous quantity of hornblende which occurs in the mass of the reputed parent-rock should here appear, is marvellous indeed;—and little less marvellous is it that the alkali-charged felspar should have here proved more unalterable than the hornblende; a result demanded by the hypothesis of the formation being formed solely, or even largely from the debris of that which is at present the sole subjacent rock.

The second difficulty connected with the constitution of these gritty strata, is the very large amount of fine-grained porphyrys, and especially of colloidal silica,—as seen in jaspers, cherts, and vein-hornstones,—which goes to form its pebbles. This is vouched for in those portions of the above quotations which I have italicized. The parent-rock which yielded these jaspers and cherts must have been pervaded in no ordinary degree with veins and rents which had been plugged by colloidal exfiltration. Now the underlying gneiss is not only markedly deficient in such veins, but, so far as the writer's observations go, it is *absolutely* deficient in them,—if the one cherty vein near Cape Wrath be excepted.

How is this great and almost uniform admixture of colloidal silica to be explained, unless it be admitted that some series of rocks, of which no vestige has yet been found in the district, had yielded something towards the formation of the Conglomerate? The vast amount of this durable siliceous vein-debris, of itself vouches for the destruction of some great formation.

Dr. Hicks writes,—"These conglomerates and sandstones appear to have been shore or shallow-water deposits; and fragments of the underlying gneiss are abundant in them. Associated with these, however, are other masses which do not seem to have come from the immediate neighbourhood, or at least from any of the areas which I visited. These are chiefly bits of greenish, purplish, and reddish slates, schists, jasper, &c., similar in many respects to those found in the Cambrian conglomerates in Wales, and which were there undoubtedly derived from the underlying Pebidian beds. It is therefore quite possible that in some other areas, not far distant, representations of these Welsh pre-Cambrian rocks may be found."

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These are matters which it behoved those who maintain that the so-called Cambrian Sandstones of the north are *solely* formed of the underlying gneiss, to account for, before they assigned correlative names.

There is another marked feature of the beds of this rock; it is that, though it may be said that the coarser conglomerate beds are to be found at the bottom of the series, as seen on the shores of Handa, the foot of Suilven, &c., yet the upper beds here and again, are of a coarse structure; and even when of a finer grain, occasionally contain large fragments, of angular form.

Dr. Macculloch says "It is rare indeed to find any bed which, however fine in its predominant character, does not somehow contain larger fragments. There is also no connection between the structure and the relative place of the stratum in the order of super-position; as the summits of the highest mountains, equally with the lowest beds of which they are formed, present extensive masses in the conglomerate."

The very summit of Teallich (Kea Cloch)—the highest, as it is probably the uppermost point of the whole formation,—the writer found to consist of a very coarse and loose-structured grit.

While this intercalation of coarse-grained or conglomeritic beds is a recognised feature of other formations, it is one which is exceptionally difficult of explanation when the absence of one of the ingredients of the "parent rock" is considered,—if the lower gneiss be the only possible parent rock.

It need hardly be said that no minerals occur in this formation,—veins being unknown in it; and that no fossils could be expected in it. Nicol, however, mentions having observed on the south cliff of Quinaig a few traces of *azurite*.

Its true correlation with the rocks of other localities must therefore depend, firstly, upon a perfect acquaintance with the features and the ages of those formations out of which it was formed, as well as of those between which it is intercalated. Can it be said that such acquaintance has been attained to?

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The Quartzite.

Two things are indisputable as to this rock;—the first, that it overlies the conglomerates unconformably;*—the second, that the myriad worm holes which pervade it, prove it to have been once the yielding tenement of animal existences.

The metamorphism which has agglutinated its grains is complete; but these grains being of silica and almost of silica alone, metamorphism could out of it form but one mineral body.

No veins occur in it; and it it had almost to be written of it as of the conglomerate—"no minerals occur in this formation." It is not altogether so, however.

The formation, if we regard it as an independent one—which may prove not to be admissible,—has, where it is in its most perfect development, been generally divided into two great series of beds, which are separated from each other by a number of beds of "limestone." This is a reading, however, which has far from met with universal acceptance. What the writer's explorations enables him to vouch for is,—

That at the far-southern limit of the formation, an almost vertically-tilted quartzite will be found immediately opposite to Kyle Akin in Skye,—with lime neither visibly beneath it, or overlying it.

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*I have been much surprised to read, in a foot-note to an excellent paper by Professor Bonney on the Petrology of the neighbourhood of Loch Maree, the following—"My friend Mr. L. Ewbank, tells me that near Dundonnel (Little Loch Broom) he traced a gradual passage from the one to the other," (*i.e.* from the conglomerates into the quartzite) ** the break therefore is probably rather local than general." My surprise was occasioned not merely by the conclusions of Murchison,—and, *as regards this point*, it may be said, of every one else,—being set aside in a foot note, and upon the evidence of of certainly a comparatively unknown man, but from the *Dundonnel district* being quoted as proving conformity. Though I have not examined the district named to nearly the same extent as I have done those to the north, I have no hesitation in saying that it exhibits a very much more highly marked *unconformity* of the formations, than is seen in the northerly districts. In referring to this point in the previous number of the Magazine, when speaking of Quinaig, I stated that the general dip of the conglomerate might be put at 5°, and of the quartzite at 7°. Now, as we proceed southward, the dip of the conglomerate increases, as does that of the quartzite, but that of the latter does so in a very much greater degree. In other words, the amount of diagonal denudation of the conglomerate is much greater in the southerly than in the northern districts. To anyone who doubts this, I would recommend a study of the manner in which the quartzite sweeps up over the denuded, and at some points, actually fretted beds of the great hill Teallich: or a consideration of the sections to the south of this, given by Geikie in the XVII vol. of the Quarterly Journal of the Geological Society.

Professor Geikie and I have, in companionship,, gone over a not inconsiderable portion of this northern district; I have seen his pencil working, and I can vouch for his accuracy. I can also vouch for his caution, for he has asked me to climb to doubtful points, and trace out flexures;—demonstrating to him while he drew beneath. As to the "break being rather local than general," I have only to say, that, while I have seen one or two points where there was an *apparent* conformity when examined *along the strike*, I have seen no spot in the whole distance between Kyle Sku and Loch Torridon where there was not a palpable unconformity, when examined *at any angle thereto*.

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That at Loch Kishhorn, a high-tilted mass of limestone shows quartzite neither below it or above it;—though here an underlying quartzite may have been faulted down,—the fault forming the Loch.

That from Loch Broom to Loch Urigill there is a continous belt of quartzite conformably underlying the lime, but none above it; (unless a wedge-shaped mass to the south of Loch Urigill, which, however, seems to have been faulted there, be in that position). Throughout the whole of this stretch the lime is either immediately overlaid by the flaggy schists of the upper gneiss, apparently conformably, or a so-called "igneous rock" intervenes,—this latter being generally conformably interbedded.

That the fair reading of what is visible in the Loch Erribol district is that there is both a *lower* and an *upper* quartzite.

But he maintains that the ground in the Stronchrubie, Ben More, and Loch Ailsh district, is so concealed by vegetation, so cut up by faults, and so dislocated and fractured by igneous intrusions, that no conclusions can be drawn therefrom:—and he will even say, that those who maintain the correctness of the reading referred to, have neither shown that they have sufficiently examined this district, nor have they submitted sections thereof such as entitle them to found upon it, or which could satisfy others that this is a district which can be referred to as proving their contention. The easily accessible and the clear sections have been cited as sufficient;—but it would have evidenced more thorough work, if the doubtful and the difficult parts had been unravelled. Had this been done it would also have evidenced a greater amount of that deference to the opinion of dissentients, which courtesy demands; seeing that this district has been brought forward by these dissentients as supplying proofs and furnishing grounds for a totally different interpretation. The extreme difficulties of this district stand also as an abiding rebuke to the arrogance of those flying visitants, who conceive that it is a question which can be pronounced upon after a sojourn of a week in the country.

Much of the difficulty connected with this district would be overcome if it could be clearly shown whether a fault exists between the Maolack-Corry lime and the quartzite of northern Bræbag. The writer examined the ground for half-a-day, he could see no evidence of a fault, and regarded the line of quartzite cliffs as a wasted outcrop. He therefore believes in an *upper* quartzite; but he must insist upon the obscurity of the ground even here, and upon the many difficulties which occur in the troubled neighbourhood.

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In presence of what is here seen, and what is *not* seen, he is far from favourably impressed with the general style of work, or the candour of those who can write—arguing on the one hand,—"There may be a few sections difficult to read, but when time and labour are given, they are all clear;"—or of those who, unflinchingly adopting the opposite view, reiterate assertions as to there being everywhere "a clear order of superposition," and "a regular and unbroken ascending order."

If the reading of both a lower and an upper quartzite be the correct one, and the system be considered as a whole, it has to be said of it that there are localities where it is so condensed in space, that quartzites and limestones alike have shrivelled into a bulk not exceeding the thickness of the face of an average quarry; and where the individuals of the many layers are reduced almost to sheets. At other localities again, there is such an ample development of all, that they separate from each other by miles in distance, and are separated geographically by stream, and lake, and valley. In its thinnest and most condensed development it is represented by cliff-escarpments possessed of noble features; while in its most developed, the larger individuals of the series present themselves as lofty hills, and split up into beds of marked dissimilarity of feature.

If there be two great series of beds of quartzite, that held to be the lower is everywhere persistent, but it is much the thinner. This lower bed is so positioned as frequently to form the summits of lofty hills;—but from consequent greater local denudation, it there occurs as a sheathing-cap, of a thickness which is far from as great as that of the series of beds which have been held to lie above the lime.

This quartzite contains the characteristic "worm-holes" very much more sparsely than do the "upper beds." It is frequently highly-stained with ferruginous matters, which gives it a purplish-brown tint. The colouring matter of both quartzite and conglomerate has been termed "ferrite"; but as this was the name given by the late Wallace Young to a magnesian pseudomorph of olivine—its use here is inadmissible. Where the rock is deeply stained, the "worm holes" are colourless. It is also to be observed that in almost all cases the sand-grains which fill these holes are smaller than those of the general mass of the rock. It would almost appear that the slimy matter which the "worm" left as a sheath to the tube, had acted as a species of filter, in keeping back any but the finer particles of sand from passing in to plug the spaces left vacuous after their own decay.

This "lower quartzite" contains within it, in one hill, numerous beds of porphyry.

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One of these beds is stated by Murchison, on the authority of Peach, to lie *beneath* the conglomerate, and between it and the gneiss.

The locality where Peach observed this, is the south-west cliffy frontlet of the Hill of Canisp, a little east of Lochanfad.

Looking from the edge of the overhanging cliff, this position did not appear to the writer to be rightly assigned to this bed of porphyry. A little beneath the summit of Canisp, he found several beds of this porphyry intercalated among the beds of the quartzite. About 300 feet below the summit, on the east side, these beds come to the surface beneath the turf, and have suffered disintegration :—the paste of the rock presents itself as a greasy clay ; and the previously-imbedded felspathic crystals, but slightly altered, lie loose, and may be gathered in handfuls.

This is one of the most striking porphyrys in Scotland.

A structureless paste of a buff or dull-brown colour is studded in single and isolated arrangement with crystals of a bright brick-red colour, commingled with others of a pale ochre-yellow tint, and with minuter ones of a dark green.

The red crystals are from half-an-inch to an inch in size ;—the white ones not half of these dimensions ; while those of dark-colour are under an eighth of an inch.

Not unfrequently the red crystals are surrounded by a sheath of the cream-coloured material, of nearly an eighth of an inch in thickness ;—and very rarely indeed, the red crystals inclose those of the pale tint. The dark crystals occur imbedded both in the paste and in the pale crystals, but not in those of red tint,—these therefore would appear to have been the first formed.

The red crystals are *orthoclase ;* even the loose crystals of which seem to have suffered no decomposition.

These yielded :—

Silica	63·538
Alumina	17·363
Ferric Oxide	1·867
Manganous Oxide	·384
Lime	1·335
Potash	12·932
Soda	1·695
Water	1·123
	100·237 (H.)

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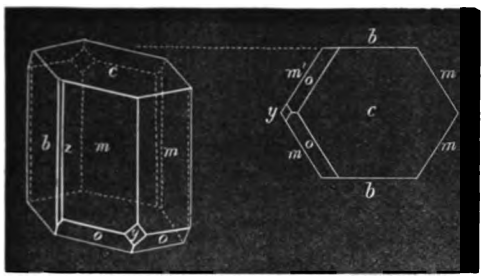
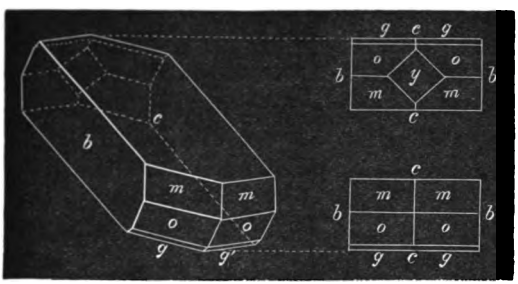
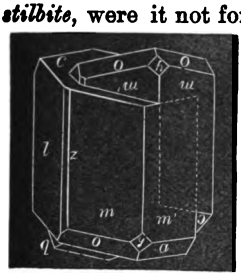


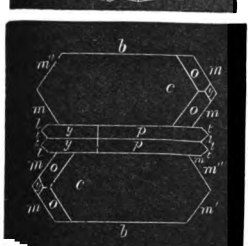
The crystals cannot be freed from the matrix so as to be figured; but those to be gathered from the surface of the spongy clay are free from adhering rock, and are of well pronounced forms. They are usually of the form in the first figure, *c m b z o y;* but the face *z* is seldom present.



In many, the faces *m b* are much more elongated than in the figure; and one crystal was got in which these faces were so much shortened that the crystal was as drawn in figure 2. This is hemimorphic as regards the face *y*. From the very unusual dominance of the faces *c*, this crystal much simulates one of red *stilbite*; and either of the terminations of the crystal, as seen in the drawing, might be taken for *stilbite*, were it not for the presence of the faces *g*. Indeed, as the writer has already shown that in *stilbite* a face occurs in the very position of this face *g*, and as this new face might have been hemihedal, the presence of the face *g* here, could not of itself show that this was *not* a crystal of stilbite.



Twins of *c m b z o y* occur somewhat rarely; they are interpenetrating, as in the figure.



There are also rarely to be found most interesting apposition twins of the same form; these are separated from one another by the interposition of a revolution-twin of *albite* (?) of the form *m p y l t*. This medial twin is not altogether so simple, or single in form, as drawn in the figure; consisting in parts of a number of smaller crystals,—all lying the same way however. The difference of colour hese crystals makes this a very singular arrangement.

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The *c* cleavage of these crystals is very eminent; and it sometimes discloses a very singular structure in the crystals. The annexed drawing exhibits this. The general mass of the crystal is traversed by a system of transverse lineations, which will be more fully described afterwards; and at either end of the crystal there is a quantity of matter of a lighter tint of colour,—possibly an intermixture of *albite*,—disposed in a plumose and a tassel-like arrangement. The surface of the cleavage-face is of brilliant lustre, but the material of these singular intruded structures, is lustreless.

The difference in the arrangement of the intruded substance, at the opposite ends of the crystals, is perhaps hardly sufficiently marked to indicate an opposite electrical polarity in these ends.

I have, in the above, called the cream-coloured crystals which are associated with the red orthoclase, *albite*. In a paper upon Scottish Felspars which was laid before the Royal Society of Edinburgh, I termed them *oligoclase*, but stated that they might prove to be *albite*. My chief reason for then considering them to be *oligoclase*, was that they manifestly decompose more rapidly than the accompanying crystals of *orthoclase* do; and we know that, as a rule, *albite* is the more durable mineral;—indeed I shall afterwards have to show that *albite* may be formed by transmutation, out of *orthoclase*.

The loose and possibly slightly-weathered crystals of cream-colour yielded on analysis.

Silica	64·439
Alumina..	20·436
Ferric Oxide	·877
Manganous Oxide..	·384
Lime	1·333
Potash	1·135
Soda	9·962
Water	1·463
	100·029 (H.)

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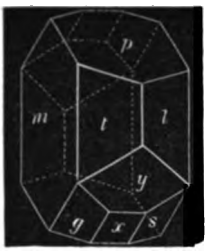
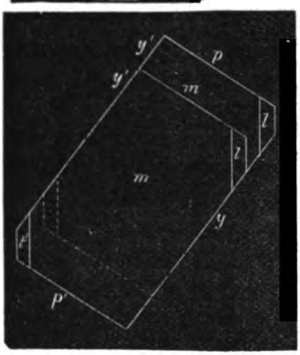
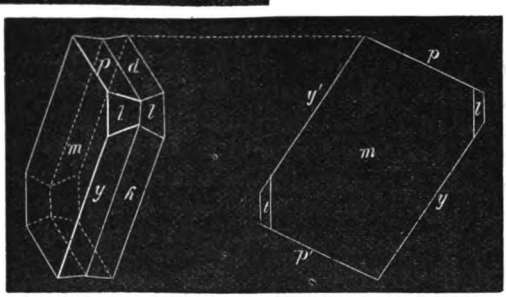


This analysis does not clearly indicate to which of these minerals—*oligoclase or albite*—the crystals belong. Certain of the crystals show striation, while others do not.

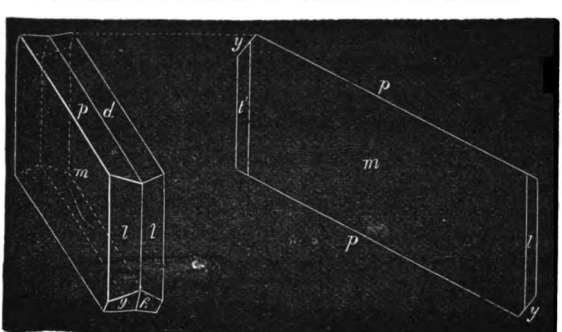
The forms in which they occur are fairly well pronounced;—but the faces of the crystals are too dull for measurement; so that no absolute determination can therefrom be obtained.



I got but a single *simple* crystal; it is in the form *p m t l g x s y*. The form *p m t l y* also occurs in *pairs* of simple crystals, attached to one another by the face *m*, but with the faces *p* not on the same level; being as drawn in the second figure.



The same form also occurs in hemitrope crystals; these, from a greater or less dominance of the faces *p* and *y*, present the marked difference in form which is shown in the adjoining figures.



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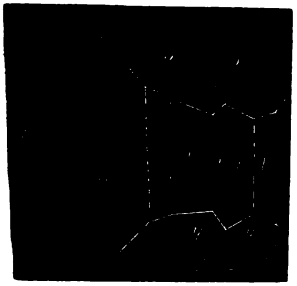

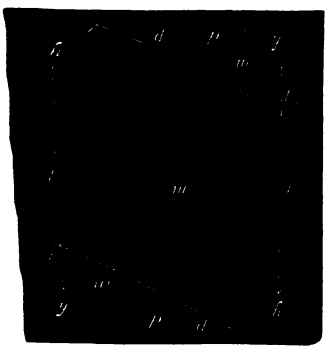

There are also hemitropic twins, of the form *p m y s l t*. In these twins, one half, or one individual, as the case may be, exhibits striation,—showing itself to be composite,—while the other does not do so. A single twin of revolution round a vertical axis, of the form *p m y t l*, was found; —a plan of this is given.

All the above are forms which accord with that of albite; but they also equally accord with the form of oligoclase.

The crystals of this felspar which lie imbedded in the rock, do not show traces of weathering; they have the colour and lustre of bleached wax. They were prepared for analysis,—P.

Sections of these crystals exhibit beautiful striation in the polarising microscope.*

The dark crystals are apparently *augite;* possibly some are *pinite.*

Murchison, speaking of the above porphyry, remarks that "no igneous rock has yet been observed to be associated with the lower quartz rock of Assynt;" and that "the large crystallised porphyry clasped round the lower part of Canisp, is interposed between gneiss and the Cambrian," and ushers in the accumulation and deposition of its coarse sediments; and that "Thus one of the earliest coarse sedimentary accumulatioms in the crust of the globe seems to have been ushered in by the eruption and spreading out of porphyry, associated with red conglomerate." He elsewhere says that this porphyry may be considered for the present to be characteristic of the Cambrian age in the North West Highlands.

Referring to the above, Nicol remarks, that "in 1859 he found that this very beautiful porphyry not only breaks through the quartzite of Canisp, but forms a mass more than a mile in diameter—in the same

* A piece of the rock was got which had a very perfect and fine twin, imbedded in it, showing beautifully the angle of *t* on *t*. The measurement of this would have settled the question as to whether these crystals were albite or oligoclase; it was therefore sent to London to be sliced, but it was broken through the carelessness of a workman.

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"lower quartz rock" within a few hundred yards of the Inn of Inchnadamff.

Referring in the first place to Murchison's statement, I have to say that the only spot in which I could see it to "clasp round" in any whit the lower part of Canisp, was "in the depression between Canisp and Suilven." This was at a spot where, through absolute denudation of the "Cambrian," the quartzite lay upon the old Gneiss; and this porphyry, so far as I saw, was solely in loose masses which might have fallen from the interbedded bands above. I have indeed, *nowhere* seen any of this conglomerate in connection with the "Cambrian."

I have already borne out Nicol's statement as to its association with the quartzite; though I have never seen the point where it "breaks through the quartzite," nor have I seen the mass in the neighbourhood of Inchnadamff.

It is to be regretted that Nicol has here (as he has at other times) imitated Dr. Macculloch in a want of precision in defining his localities. A locality is a witness, which the opposite side has a right to see and examine—or its evidence cannot be taken. As it now stands, however, it must be held that this "large crystallized porphyry," if characteristic of any formation, is so of the Lower Quartzite and *not* of the Cambrian.

The "Upper Quartzite" is apparently more highly metamorphosed than the lower—the grains being almost agglutinated.

In one spot near the summit of Ben Uarran I observed secondary quartzose veins traversing it, in which there were crude *rock crystals*.

In the cliff face which overhangs the little lake which lies between Ben Uarran and Meall Naiarloch, I found *psilomelane*, which acted as a cement to a breccia of quartz.

This "upper quartzite" has, in the hill of Brœbag, a thickness of nearly 1,500 feet, and it is here very distinctly bedded. On its south-west foot, overlooking the Fiar Loch, there occurs an interbedded sheet of a dolerite, very similar to one that occurs at Stronchrubie, in the lime. *Labradorite and augite* are evident in this rock.

A bed which occurs in one of the craggy knolls which lie between Hope and Heilim ferries, exhibits where weather-polished, a structure which speaks of such an arrangement of particles as would have resulted from the motions of mollusks or annellids among its grains when these were subject to ready displacement; the feebly-defined laminæ being looped up in festoon-like gatherings.

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The "Limestone."

Overlying the "lower bed," or intercalated, as has been held by some, between the two great series of beds of quartzite, there lies a deposit of limestone.

This deposit, which has frequently been described as a single bed, in reality consists of several beds. These differ considerably from one another in appearance, and they are separated into a thin lower and an upper set by a bed of silicious rock of a fawn or slightly ochrey colour. This very much resembles a bed which underlies the lime,—one which from its containing ill-defined organisms somewhat resembling fucoids, has received the name of "the fucoidal bed."

As these intercalated strata of limestone have been correlated with a set of beds which lie in uncovered exposure in the district of Durine, and as all recent speculation as to the age of the whole series of the Sutherland rocks has been based upon the occurrence of Silurian fossils in this latter deposit, it is needful to consider the geognostic features and the chemical composition of these limestones somewhat in detail.

The occurrence of two sets of beds of quartzite has been detailed above, in terms which imply little doubt as to the accuracy of the fact, in the north of the county. Near Hope Lodge, the system of beds is so amplified by the intercalation, or perchance increase in thickness of beds which are of a gneissic structure, that, *if there were no suspicion of the southerly continuance of the Whitten Head fault*, the sections there may be read as showing that here, the upper bed was separated into three distinct beds; and that the quartzite series in this district shades off into the overlying gneiss.

In like manner it has been held by some, though the statement has met with vigorous opposition, that there occurs an upper and perfectly distinct set of beds of limestone; and that these overlie the chief mass of the upper quartzite.

The writer believes that much of the difference of conclusion which has been arrived at on the first point is due to local amplifications, or local thinning away of the beds, not having been duly considered.

As regards the second, he holds the opinion that the upper limestone bed occurs among the beds of the upper gneiss as distinguished from the quartzite.

The argument that this so-called *upper bed*, the position of which is not pointed out except at one spot, has at others absolutely thinned off, is in its necessary consequences far from a satisfactory one; for while *that* argument might in itself be granted, it is stretching probability beyond all reasonable limits to require that the very characteristic rocks or series

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of rocks which accompany the lime, as seen at that one locality, as well as all the beds which intervene between it and the quartzite, *should have likewise disappeared.* The so-called upper lime of the quartzite has been searched for in several of what were considered likely spots for finding it or its associates, but wholly unsuccessfully.

Were it not for the intervention of the gneissic beds, we should, however, admit that the amount of amplification or spreading out of the true limestone series is elsewhere so great, that comparatively little more would bring this upper lime within its bounds.

The system is for miles of the long stretch of road between Knockan and the Loch Broom shore so condensed that it forms but a low cliffy bank to one or other side of the road. Standing here upon the "upper gneiss," where its first beds lie upon the lime (there is here no upper quartzite), we can spring right over the low cliff, and light upon the road cut in the quartzite; or a little further south, standing upon the top of the quartzite, spring over its whole thickness of perhaps ten feet, on to the underlying conglomerate. Nay, so "condensed" are both of these rocks here, that it is quite probable that a spot might be found where the observer might stand upon the upper gneiss, and in half-a-dozen paces find himself upon the Torridon Sandstones.

An inspection of the lime and quartzite here, however, will shew that they consist not of one bed, but of many; and when we follow them along their grand expansion in Knockan and Elphin, we are guided to the Stronchrubie range of cliffs, the scalped summit of which stretches back for miles to the east:—for so many miles that *visibly* they cover more than half the ground which intervenes between their lower members and the so-called "upper bed" at Loch Ailsh.

Another cause to which the discrepancies which are found in the statements of writers is very probably due, is the manner in which the lime, quartzite, and indeed the whole district in which they occur, is cut up by intrusive rocks. In certain localities there appears merely a bed of very uniform but very inconsiderable thickness, which lies among the layers of the lime itself. But here and again an igneous rock—it may not be the same—presents itself in enormously augmented bulk; and, perhaps as a petrological consequence, it is so markedly altered in structure and appearance as not to have been always recognised as having any connection with that in the lime itself. Beds of lime, which are separated, as at Stronchrubie, by a sheet of igneous rock of half-a-dozen feet in thickness, are not unlikely to escape recognition when separated thousands of feet from each other by bossy amplifications of that igneous rock; and when they have moreover become highly metamorphosed by the greater amount of heat which that ampler bulk must of necessity have evolved.

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Moreover, seeing that the igneous rock of Stronchrubie is much of the the nature of dolerite, while the larger masses of eruptive rock tend much to the character of a quartz-porphyry, a larger amount of proof that they belong to the same intrusion may be demanded, than can be disclosed in a tract of country which is swathed in the verdure which is the product of a limestone substratum. And, if the proofs of such connection be deficient, then the identity of the associated limestones or marbles must in fairness be said to be open to question.

Throughout the whole of its range from north to south, the features of this limestone do not much vary. When fresh broken it is grey in colour, and it weathers to a dull yellow tint. Some of the beds, as at Stronchrubie, and to a smaller extent at Elphin and Knockan, rarely contain thin bands of flattened nodules of pale red *chert*, arranged in close proximity, like chalks in flint. The rock is one which is not much affected by atmospheric influence,—except where here and there running waters cut "sinks" and "swallows." It nowhere exhibits pinnacles or turrets, or a crumbling structure, but rears its escarpments aloft in sheeted cliffs, massive in form and enduring in appearance. And that appearance is almost unvarying.

Calcitic veins at the Heilim quarries contain ill-developed crystals in "dog tooth," "nail-head," and other common forms. With this single exception it nowhere presents a variegated appearance.

In no part of its extended stretch has this limestone yielded fossils. White calcitic bandings somewhat resembling organisms were in a single case obtained from the banks of one of the streams which enter Loch Stack from the north east. They were found by Dr. Joass, Mr. Dudgeon, and the Author. These calcitic markings were ill-defined, and were probably chance segregations of the purer portions of the calcareous matter.

The composition of this limestone is very similar, from whatever locality it is taken. It is fortunate that an extensive series of analyses of it have been recorded, *before* the differences of opinion as to its age, and its identity with other masses in the country, had arisen.

These analyses must therefore stand as unprejudiced witnesses in determining its nature.

Dr. Thomas Anderson many years ago published, in the Transactions of the Highland Society, the following analyses.

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	$\dot{C}a\,\ddot{C}$	$\dot{M}g\,\ddot{C}$	$\ddot{Fe}_2\ddot{Al}_2$	$\dot{S}i$	Total.
Erribol	51·04	41·36	·9	6·41	99·71
Achmore (pale bluish grey) ..	53·51	43·20	·35	2·68	99·74
Do. (darker, more crystallised)	54·88	41·85	·22	3·	99·95
Stronchrubie (white crystallised)	45·79	48·72	1·33	1·77	97·61
Do. (dark grey)	48·	42·01	·48	7·51	98·93
Knockdhu, Elphin (bluish grey)	41·58	33·47	1·92	23·07	100·04
Do. (greenish grey)	53·77	41·01	1·08	1·56	97·42
Kirktown	50·21	41·22	1·57	6·	99·
Do. (grey and earthy).. ..	51·33	41·08	·74	6·42	99·57

Throwing out of consideration the silicious and aluminous contaminations, the averages of carbonate of lime and of carbonate of magnesia are 50·01, and 41·56 respectively. These, brought up to 100 parts, give

Carbonate of Lime	54·61	54·35
Carbonate of Magnesia ..	45·39	45·65

The second percentages are those of Dolomite—so that *the rock is not limestone*, but an exceedingly typical *Dolomite* throughout.

The Marbles.

Sir Rhoderick Murchison holds that one of the members of the quartzite series is an upper limestone—that is, one which overlies the the upper quartzite. He gives to this a sweep which, passing from the south eastward of Loch Ailsh extends far behind Ben More, and even north eastward of Ghorm Loch. This in its northern portion, however, he states upon hearsay evidence alone.

As the calcareous rock of Loch Ailsh is in almost every spot a *marble*, it fails to be considered along with these.

The marbles of Sutherland were worked for some time in the neighbourhood of Loch Awe in the Inchnadamff district; but, on account of the presence of gritty particles which cut the polishers, the attempt to work them was abandoned.

This defect is much to be regretted; for, judging from specimens which were at the time polished as samples, and from such fragments as can now be picked up at the old workings, these marbles were not only characterised by pleasing tints and well disposed markings, but they were much more variegated in their characters and mode of colouration than is usually to be looked for in a single locality.

From the neighbourhood of Ledbeg, the writer obtained yellow and green serpentinous marbles, along with others of a chocolate brown, and of a lively red.

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Most of these specimens, however, when placed in acid, left behind rosette clustres of doubly-terminated quartz ;—these sufficiently account for the destruction of soft polishers.

Little of the marble here is spotless or devoid of colour.

Now the question is, what is this marble? It lies very much in the strike of the great escarpment of Stronchrubie, about four miles distant; but it itself is a mere "bunch," which is pinned in between a trap dyke and the red quartz-porphyry of Cnoc na Strome. Have these metamorphosed it? or are we to assign the change to the large mass of the so-called "igneous rock" which forms the hill of Cnoc an Ledvui? The rock of this hill cannot be traced into actual contact with the marble, for the ground is covered; but if not from it, it is difficult to see from whence the serpentinous ingredient can have come.

From a point immediately to the south of the Ledbeg river, as it issues from Loch Borrolan, the writer has traced a pure white marble, which occurs, however, only in rounded and isolated patches, for a distance of one and a half miles to the north-east shores of Loch Urrigil; it is again to be taken up on the south-east shore of the lake, and it continues in a similarly interrupted manner as a series of deep pots, each supplying food and shelter to a birch sapling. It is lost sight of, eastward of one of the faults of a let-down wedge of quartzite, in the near neighbourhood of Elphin.

At one part of this sweep, near the north shore of Loch Urrigil, it is in close association with, though not immediately overlying a highly vitrified quartzite. Which member of the quartzite this is, is not clear, as a north and south dyke-filled fault cuts the burn of Urrigil.

In no part of this sweep is the igneous rock to be seen, and an extensive bog entirely hides everything to the eastward.

From the close approximation of crumbling *upper schists* in the banks of the Ledbeg river, nearly as far west as Ledbeg,—from evident indications of a fault in the line of sinks east of Loch Borrolan,—and the close approach of the upper schists in the hill Meoirburn, there can be little doubt that the marble of the bog between Lochs Borrolan and Urrigil is the same marble as is to be seen at Loch Ailsh, let down by an extensive east and west fault.

The Loch Ailsh marble is first to be seen immediately to the north of the mail-coach road. It is here in two distinct beds;—the lower, a pure white saccharine marble, is not to be distinguished from that of Loch Urrigil. This is separated from the upper by a band of muddy chert, which apparently contains obscure organisms, and also by a bed which has been called hornstone porphyry.

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The overlying bed is not perfect in its metamorphism, and approaches in character to a granular limestone.

The course of these beds is very obscure in their northern extension, they are separated to a great extent. That which is truly marble apparently sweeps round to the south of the hill Scoonan. Marble can be seen in a large "sink" immediately to the south of the col, between that hill and the first heave of Bræbag. This col is formed by a north and south fault which cuts through the ridges.

In this col, loose slabs of a rock much resembling the fucoid beds, appear; and though neither limestone nor marble is seen in association with these yellow slabs, yet the close proximity of the marble at the foot of the hill is a strong argument in favour of its being merely the altered limestone.

Scoonan, under which these yellow beds dip—or which cuts them off—is itself the "igneous rock."

High upon the eastern extremity of its ridge, the out-crops of quartzy schists, perfectly similar to those of Loch Ailsh, are seen. These out-crops have fallen shattered, like a curled-over breaker, into a peat bog;—this not improbably conceals some washed-out beds of the lime. The appearance here is unique;—there are two or more of these ruinous out-crops, with finely jointed and squared slabs of white rock impacted in the black paste into which they have toppled over. It might thus, from its position, be affirmed by some that here the igneous rock of Scoonan "occupies the place of the limestone."

An escarpment of the yellow beds can be traced along the north bank of the Strathan Water, due south of Dhu Loch More, and lime is again met, with a north easterly dip, in the balloch or great col between Coineveall and Bræbag. If there be not a fault it would plunge under the huge quartzite cliffs of Ben More, and would sweep north westward in the precipices of Ben Harran in the direction of the outcrops which occur north of Inchnadamff on Croc an drien.

Whether it is continuous with these or not cannot be *absolutely* determined, on account of the fault which there cuts the lime and inclosing quartzite off from Ben Harran; but some thin beds first sweep up among the cliffs, and ultimately curve over and downwards to the fault. This curvature is not so much a flexure of the quartzite, as the result of a number of small faults which radiate, as it were, from a centre positioned below the centre of the hill.

The other—the upper and easterly bed of the limestone,—is to be traced to about the north end of Loch Ailsh, along or above the eastern shore.

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It is immediately overlaid by highly gneissose flags; these, though having some slight resemblance to quartzite, are evidently members of the upper gneiss.

From this point Murchison says that it "sweeps round to the east and north of the mountain of Ben More, and extends up the valley of the Dashley to the side of the Stack of Glen Coul."

Immediately north, however, of the spot where the lime is lost, the gneous rock forming the Eagle Craig and the craggy hills S.E. of Ben More, comes in.

There is probably no part in the whole stretch between the Whitten Head and Loch Kishorn, in which the country is so cut up by great faults and troubled by igneous intrusions as is this. It cannot be admitted that it is a locality which it would be at all safe to adduce for the the establishment of "a regular ascending series"; and while it has to be noted that there is elsewhere,—*i. e.* in the untroubled districts,—no evidence whatever of a true upper-limestone *of the quartz series*,—that is, superior to all the beds of quartzite,—it might also be held that as far as stratagraphical position is concerned, the limestone of the col, and the marble of Scoonan, may be but members of the series which occur elsewhere condensed, and are here separated widely from the other members, either by local amplification of the thickness of the quartzose beds, or by the interstitial intrusion of the masses of igneous rock. These are here very much greater in bulk than anywhere else along the whole line of their occurrence.

If it be held that the lime which occurs in the col between Bræbag and Coineveall is an upper-limestone, *because* it manifestly overlies the quartzite of Bræbag, and *because* the quartzite of Bræbag overlies the Maolackcorry lime, then it must be held that there is also a still higher quartzite; for the whole of the quartzite of Ben More, probably 1600 feet in thickness, overlies *it*. This is a rendering which is quite admissible, as Cunninghame long ago showed that at Drum Tungi, above Heilim, there was such an upper quartzite; and the close association of five beds at this locality would reduce all to fall within the writer's view, that any *upper* lime or *upper* quartzite is but a local opening up of what is elsewhere a condensed system.

No lime overlies the quartzite of Ben More proper. The writer found that the sharp ridge of the hill all along the "Saddle" and "Bad Step," was formed by the edge of the uppermost band of the quartzite, which was padded with a plastic clay; and this clay when dug into was found to pass into an unctuous margarodite schist.

If any lime occurs where Murchison places it,—away to the back of Ben More, it must, like the Shinness lime, be a member of the upper gneiss.

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The character of the rock of the hill which lies immediately west of —that is below the Loch Ailsh lime—is very obscure. It may be described as being intermediate in appearance between the so-called "igneous rock," so frequently mentioned, and a chloritic schist; whatever it be, it evidently separates this lime from the true *quartzite series of limestones*.

It has to be mentioned that the present writer has questioned numerous individuals, and especially those who surveyed the route of a proposed road from the head of Loch Shin to Loch Coul, as to whether there was any lime in this district; he invariably received a negative reply.

An analysis of the Marble of Ledbeg is given by Dr. Anderson. He obtained

Carbonate of Lime	91·32
Carbonate of Magnesia	4·74
Alumina, Ferric Oxide, &c.	·2
Silica	4·34
	100·60

It therefore is a true marble, and differs entirely from the dolomites of the quartzite.

In the first edition of Phillips' Mineralogy, *schiefer-spar* is noted as occurring in the limestone of Sutherland;—it may have been from one or other of the marble quarries, noted during the time when they were being worked.

The Durness Limestone.

After much contention it has now been agreed* that this is a fragment let down by faults which intersect at three points. It has been let down

* It is not altogether easy to make out whether Sir R. Murchison ever was among those who so agreed; nor indeed, is it easy to arrive at any conclusion as to his views. Writing in 1858 we find that on one page he says regarding them—"the ascending order of the quartz-rocks and limestones is everywhere the same as in Assynt, *i.e.* a strong band of limestone interposed between masses of regularly stratified quartz-rock." Two pages further on he writes—"The reversal by which the Durness limestone is thus placed in a trough of quartz-rock and underlying limestone, has been manifestly occasioned by a great upheaval of the old gneiss when acted upon by eruptive forces, of which clear signs are manifested in the adjacent Bay of Sangoe. There huge bosses of black hornblendic and hypersthenic rock stand out with serpentinous coatings,—the courses of the limestone in their vicinity being singularly altered, mottled and dolomitic, —"there is no doubt that the limestone and underlying quartz-rock of Durness occupy a trough." In 1859 again he writes—"This tract has been subjected to so many dislocations, that in one line of traverse only, or that in which my former section passed, can it be viewed as unbroken,—no other section represents a trough. On the contrary, the limestone is thrown abruptly into contact with the old gneiss of Kennabin on the north-east; and constitutes a narrow wedge-shaped mass between that fault and an equally large one which truncates it against the old gneiss on the west side." But other observers, *e.g.* Harkness and Nicol, have shown that so far from being "unbroken" in the line of Murchison's first section, the lime is cut up into quite a multitude of fragments along that line. The theory of a great upheaval of the old gneiss at Keannabin by [illegible] bosses of oruptive rocks in Sangoe bay, which simultaneously altered the limestone, [illegible]l advert to after.

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nearly horizontally; but, having fallen into a V chasm, it is considerably crumpled and rent, and it is cut up throughout by minor faults, generally with a north and south strike.

But where was it let down from? It seemed not only safe and rational to assign it to the nearest similar bed, but necessary withal; for, no *upper* lime being claimed for *this* locality, only one bed was known. And so, though the continuation of the rise from the islet of Chorrie over the slopes of Ben Spinnu must have positioned such a westerly continuation thousands of feet over its present rest, this fragment has been without hesitation attached to the Erribol bed.

It is like it, moreover;—that is, it has *at first sight* a general resemblance,—but "like is an ill mark."

And then Peach found the fossils,—and the fossils were pronounced to be Silurian;—and then there was a feast of correlation, and a flood of theory,—and the grand old "gnarled gneiss," which gives their noble outlines to the Highland hills, was declared to be the same as the solidified mud of the hideous hunches of the Lowlands.

If it be so, it has to be noted that no attempt has as yet been made to account for the many differences between the rocks at the two extremities of the country; and the following facts have to be explained before the Durness lime can be held to be *proved* to be but a fallen fragment of the great north and south Erribol-Kishorn bed.

1st.—*An absolute difference in composition.*

The "limestone" of the quartzite has been shown by Dr. Anderson to be, throughout its whole range in the county, a very typical *Dolomite.*

The same analyst gives, as the composition of the Durness rock, the following—

Carbonate of Lime	90·01
Carbonate of Magnesia	6·50
Ferric Oxide and Alumina	·28
Phosphate of Lime	·27
Silica	2·77
	99·87

Being a fairly pure *limestone.*

In analytically testing the accuracy of Professor Anderson's results, I selected specimens from Garve Island, as the organisms are there still to be seen.

I give the results of the complete analyses of the two *most highly magnesian* samples or beds which I found.

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No. 1 was a massive, minutely crystalline, purplish-brown variety: it contained fossils, the substance of which was white, and of a more highly-developed crystalline structure. No. 2 was grey, rotten looking, and somewhat cellular. 3 was the substance of the fossils themselves.

	(1)	(2)	(3)
Carbonate of Lime	92·	93·8	97·12
Carbonate of Magnesia ..	5·856	5·635	2·65
Silica	2·156	1·03	·97
Carbon	·31	tr.	
Ferric Oxide and Alumina ..	·19	·2	tr.
	100·512	100·665	100·74

From other trials, I should say that the average quantity of magnesian carbonate was about 3·5 per cent of the rock. The accuracy of Anderson's result is thus confirmed; and the rock proved to be chemically quite different from the Dolomite.*

Dolomitisation is a recognised geologic change; it is one which is quite in conformity with chemical interchange; it is, indeed, in certain circumstances, a necessary result of chemical requirements:—but *de-dolomitisation* is something new,—is altogether repugnant to chemical requirements,—and it would be no easy task to point to the circumstances, and unfold the processes through the operation of which it could be effected.

No law of transformation can be accepted as an established truth in science, which is revolting to any one department of science; and before the Durness *limestone* can be recognised as a fragment of the interbedded *Dolomite*, it is requisite for those who maintain it to be such, to explain this inverted interchange,—this new process of de-dolomitisation.

It will hardly be said that the exposed fragment is the unchanged material—and the swaddled-up rock that which has been transformed.

2nd.—*Difference in structure.*

It was noted above of the *Dolomite* beds, that throughout their whole range they presented *unvarying* features; the opposite holds as regards this small patch. Within the range of the few miles of its extent, it presents four such marked varieties that, from their localities, they might be called the *Dionard*, the *Balnakill*, the *Durine*, and the *Smoo* limestone.

The Dionard lime, instead of being, like the dolomite, little affected by the weather, is so readily acted upon that it is everywhere carious,—having

* An average sample of this limestone was lately forwarded by me to Messrs. King and Hunter, the city analysts of Edinburgh,—without any information as to its source, or indication that it was in any way of special interest. My instructions were to determine merely the lime and magnesian carbonates,—but to do this with scrupulous care.

These gentlemen write:—"The total CaO present is 50·82 per cent, which calculated to Carbonate yields 90·75 per cent. of Ca CO_3. The total Mg O present is 1·60 per cent, calculated to Mg CO_3 would yield 3·36 per cent. Of course some of the lime and magnesia may not exist as carbonate."

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a surface like a rasp; and, instead of the massive and sheeted rock surfaces of the former, as seen at Loch Maoloch Corry, and above Stronchrubie, we have here the features of a crumbling ruin.

The rock at Balnakill is much more crystalline than is the dolomite at any part. It is also characterised by a very singularly mottled structure. The ordinary, what may be called the basement structure of this, is a dull white; throughout this there ramifies a tuber-like structure, of size and appearance much like the dried roots of ginger. This structure is blackish in tint; but its granules are of the same size as those of the white portion, and there is not the slightest appearance of any such sharply-defined line of demarkation between the two portions as would indicate an organic origin.

In the vicinity of the village, the lime is much veined; white and red streakings traversing it in every direction.

At the last of these localities it bears much more resemblance to the great interbedded sheet of the quartzite formation; a solid and smooth-sheeted precipice,—indubitably a line of fault,—protruding boldly from the west and east shore-line, much after the manner of the out-crop at Stronchrubie.

Cunninghame writes:—"The limestone of Duirness differs from that of the rest of Sutherland, in the circumstance of containing numerous quartzose concretions of ovoidal, globular, and elongated forms, having an arrangement more or less parallel to the lines of stratification. The varieties of quartz which enter into the composition of these masses, are chalcedony, hornstone, jasper, and flint, affording a perfect analogy to those quartzose concretions which are met with in newer limestones."

3rd. *The abundant occurrence of fossils.* Not readily to be found now however. The organisms upon whose presence the foundation-stones of the geology of the whole kingdom were perchance all too squarely and smoothly fitted in, have long since been reft from the sparsely occurring scalps and turfless crags; but the cliffs around the lakelets and the rocks of the shores yielded enough to prove this to be a deposit which had sepulchred the dead in no stinted numbers.

If it be but a portion of the interbedded sheet, how came it that the organisms of this fragment which had dropped so deep,—so much deeper indeed towards the earth's core,—had escaped the metamorphism which had obliterated all traces of structural arrangement in that larger portion of the rock which lay nearer to the surface?

As regards the bulk of the rock here, there has in sooth been no such escape—the structure of the rock itself showing that it has been much more highly metamorphosed than has the interbedded sheet;—and th

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been, moreover, much more highly affected by the agents of *secondary* transmutation. Yet here, in the more transmuted rock, the fossils are; while in the less transmuted rock, there they are not.*

The very marked manner in which this limestone has been affected by secondary transmutation, should of itself have "given pause" in correlating it with the dolomite; aside altogether of the difference in composition.†

In place of the sparse and feeble development of cherty nodules which are seen in the dolomite, there are to be seen in this, and especially in those beds which in colour and structure most highly resemble the dolomite, continuous layers or belts of *purple hornstone*, in repeated and close proximity.

In the gorge at the mouth of the Smoo burn, nodules of *horny-chert*, of a cream colour diversified with black, are frequent; these occasionally disclose what appears to be an obscure organic structure. An oval black spot, sometimes with a white centre, is surrounded with a loose sprinkling of yellow chert. Upon sectioning, however, both centre and surrounding dust was found to consist of minute rhombs of primary calcite or dolomite. These had angles of such extreme sharpness as proved that the chert must have been perfectly plastic while they were crystallising.

Upon the cliff summit about midway between the Smoo Cave and the shore line, there occurs upon the west side of the chasm, a bed four to six feet in thickness, of milk-white translucent *chert* of great purity, and of a perfectly uniform impalpable structure, and a horny lustre.

An average specimen of this upon analysis yielded :—

Silica	97·769
Ferric Oxide	1·538
Manganous Oxide	·076
Lime	·301
Magnesia	·153
Water	·207
	100·044 (H.)

The specific gravity of this is 2·641.

* An examination by the microscope of the silicious residue of this lime, when treated with acids, showed nothing clearly except silicious rods, much resembling fragments of the rootlets of the rope sponge. They were very much more minute.

† Sir R. Murchison writes,—"some of the exposed points or knobs are surrounded or partially wrapped over by a tufa-like silicious sinter, sometimes resembling a breccia, which conveys the idea of a boiling over of such matters when the rock underwent the metamorphism to which it has evidently been subjected. Even in this hard matrix my companion detected traces of fossils. The most marked of the external characters of the limestone is its coarse rugosity—the result probably of weathering upon its peculiar composition, and which gives the scarps of the rock the appearance of an elaborately wrought rustic basement of a Florentine palace." While I would not ask any chemical reader to believe in a *boiling silica* remaining inert as regards the lime *over* which it boiled, still the above is a geologic admission of extreme and evident metamorphism, and "composition" "peculiar" as regards the "limestones" of the district.

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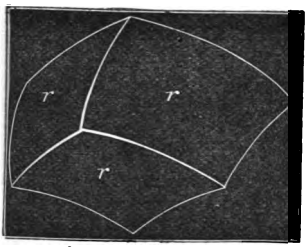

The cherty nodules of the Cave of Smoo are occasionally hollow, and contain *pearl spar* in curved crystals. These are of a fawn colour.

It certainly may be fairly adduced as an argument in favour of this limestone having been at least not far removed from the quartzite, that portions of the latter have been thrown down along with it; but these do not aid us in assigning to it any definite position, for they are themselves cut off from the lime by faults, and crushed up against it, so as to destroy all evidence of relative position. A great mass of the rocks which overlie the quartzite are also thrown down to the north, constituting the peninsular headland of Farrid. Though totally obscured by huge domes of blowing sand, there can be no question that this promontory is cut off from the lime by a cross fault. As it has, however, been let down apparently by the same great north and south fault, the rocks of this fragment may, if characteristic, help somewhat in disclosing the original position of the lime.

The following succession of rocks was found to occur at the Farrid Head—passing from north-west to south-east—*i.e.* from below upwards.

Schistose gneiss
Micaceous talcite
Gneiss
Chloritic Schist
Quartzitic layer
Chloritic schist
Lamellar quartzite
Gneiss
Laminated sandstone flag
Micaceous sandstone flag
Sand-covered fault, and lime.

The rock to which I have given the name of micaceous talcite is of a very singular description, and unmistakable.

In a kind of granular paste of a green colour, there lie glistening curved scales of the size of a bean, precisely like the inside of diminutive oyster shells,—they seem to be formed of minute scales of margarodite in a definite arrangement.

The lime which is seen at the north-west corner of Smoogro Bay is stated by Nicol to be separated from the succeeding rocks by an injected mass of hornblende rock and serpentine. This igneous rock I did not find, but only a fault.

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Traversing the shore of Smoogro Bay again, from west to east, we fine

Micaceous rock
Serpentine
Chert
Marble
Serpentine
Cherty flags
Serpentinous gneiss
Fault
Pebbly quartzite
Fault
Cherty mottled lime like the Balnakill
Fault

The striking beds in this series are what I have called marble and ser pentine.

The marble is undoubtedly a vein. It is formed in great part of interpenetrating large crystals of calcite, which have a capped structure throughout; this is developed by alternate layers of milk-white and ochre-yellow. If it could be procured in sufficiently large masses, it would prove a highly ornamental stone.

The so-called serpentine is distinctly foliated, and has palpably resulted from the alteration of a gneissic schist. Its mineral substance has more resemblance to a dull agalmatolite than to true serpentine. It is green, lined with red. It has no appearance of having resulted from the alteration of an igneous rock, and it is altogether small in bulk.

Nowhere could I find the "huge bosses of black hornblendic and hypersthenic rock" spoken of by Murchison as having been the clear agents of the upheaval of the old gneiss at Keannabin. Nor could I discover any altered limestone—or any limestone other than the one vein spoken of. In fine, I can draw no other conclusion than that this series is a fragment of the upper gneiss let down by an east and west fault—like that of Farrid Head, and highly altered, from close proximity with the lime.

Sir Rhoderick Murchison's contention, or rendering of the rocks of this locality, here falls to be considered, as therein are conveyed the *stratigraphical arguments* for the connection (or disconnection) of this lime with that of Erribol, &c.

He writes,—"The reversal by which the Duirness limestone is thus placed in a trough has been manifestly occasioned by a great upheaval of the old gneiss, when acted upon by erruptive forces, of which clear signs are manifested in the adjacent Bay of Sangoe. There huge bosses of black hornblende and bypersthenic rock stand out with serpentinous coatings,—the courses of the limestone in their vicinity being singularly

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altered, mottled, and dolomitic. Again, as we ascertained that Farrid head consisted of the old gneiss, there is now no doubt that the limestone and the underlying quartz-rock of Duirness occupies a trough."

The western or Farrid side of this trough, Murchison had afterwards to abandon; much do we fear that the eastern or cataclasmic side must be abandoned also, when the "manifest-huge bosses" which occasioned the "great upheaval" cannot be found.*

Granting, however, that they did exist,—seeing that Sangoe Bay is situated nearly in the centre of this patch of limestone, any "upheaving" forces acting there, instead of throwing it into a trough through a reversal of its eastward dip, *must have done the very opposite*,—namely, domed the limestone, and thrown it off from the flanks of the "erupting" bosses.

The nearest limestone, however, though cut up by crush-faults, and somewhat wrinkled, is nearly horizontal in its bedding; and the Sangoe rocks constitute but a disconnected fragment, cut off from the lime "manifestly" on three sides.

The actual relation of this series of rocks to the lime in the south is, however, obscured by cultivation. As the strike of the beds is at nearly right angles to their junction with the lime, there can be no question that they are cut off therefrom by a fault. Harkness seems to have noted more north and south faults than the writer was disposed to considered undoubted.

It is very evident, however, from a tongue of lime being caught in between these two fragments of the upper gneissic rocks, and from the second of these lying actually between two masses of the lime itself, that the association of these must have been somewhat intimate before the faulting took place; andas the sequence in both of the sections given is both rapidly alternating and highly characteristic, I sought for members of both among the rocks of the upper gneiss, and especially for the very characteristic "oyster-shell rock," which I had never previously seen.

This rock I (long after) found at the height of 820 feet, almost at the summit of Craig Vercan, a rocky knoll which lies directly north of Ben Hope. This position would correlate the micaceous sandstone flag of Farrid Head with the quartzitic flag of the west side of Tongue ferry; with which it indeed is identical in appearance.

Another fact of importance is the entire absence of cover to this Durin lime. Nowhere in the many square miles of its exposure is a particle of overlying rock to be seen. One marked feature of the dolomite with which it has been correlated is that it is almost everywhere *sheathed*; only

* Not upon merely petrological or chemical grounds alone, but upon geognostical also, would it be of surpassing interest if we could obtain portions of an eruptive rock which had risen *from beneath the lowest rock of the known crust of the earth.*

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outcrops being visible. It might have been supposed that, sunk down between the lofty and protecting spurs of rock on each side, denuding agents would have failed to scalp this limestone of so hard a cover as an overlying quartzite must have proved. That quartzite, moreover, has endured in low positions upon the west side of the Durin ferry and to the west of Erribol ;—as it has also in the lofty escarpment of Spinnu and Carnstackie. Hence the rational inference is that the Duirness lime was never so covered.

A few large boulders lie upon the surface of the lime, but these are of granite.

Different in composition, different in structure, pregnant with fossils, more highly metamorphosed, associated with newer rocks, altogether out of place,—it will need absolutely new evidence before our theoretical geologists are warranted in declaring this *limestone* to be a chip off that old block of *Dolomite* which now stands above it.

It might not be out of place for them to bethink themselves of the two patches of a very recent rock which occur, absolutely isolated, at Loch Greinord; and to consider if a similarly isolated patch of Silurian may not have occurred somewhere here.

Be this as it may, the two "limestones" must be held to be distinct, until it is either shown that Dr. Anderson's analyses and those of the writer—supported now by that of Messrs. King and Hunter—are incorrect,—or that the magnesia so largely present in the original rock had in the faulted fragment been removed by a process which simultaneously restored organisms which had previously been metamorphosed beyond recognition, or even ocular apprehension.

And if the two "limestones" be different, then the whole fabric of Murchison's correlation of the rocks which overlie the Dolomite, falls to the ground.

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XVI.—*On the Chemical Composition of Epidote from Quenast.*

By M. l'abbé Renard.

Read at the Swansea Meeting, August 27th, 1880.

THIS Epidote is found in the well-known quarries of quartziferous diorite at Quenast.

Without entering into any details regarding its crystalline form, it will suffice to mention that it here occurs in bacillary prisms, often elongated in the direction of the orthoaxis, and almost always macled parallel to the cleavage plane h' ($\infty\bar{P}\infty$). It also occurs frequently in lamellar, fibrous and radiated masses of a pale green color, at times greyish or straw-colored;[1] these groups of crystals, which frequently occupy the geodes of the matrix, are capable of furnishing the mineral in a state of great purity, and well suited for chemical analysis.

By selecting the material for analysis with scrupulous care, we may meet the objection recently raised by M. Laspeyres,[2] that the greater number of analyses of epidote have been made upon impure specimens. We may add that the epidote of Quenast does not exhibit those intimate associations with other minerals which are apt to occur in specimens from many other localities, and that, moreover, any microscopic contaminations can be got rid of without much difficulty. As regards included minerals, particularly quartz, we may say that we have but rarely observed any, when examining sections of the mineral under the microscope. As the crystals from Quenast are pale in color and split readily, along the planes of union, into lamellæ scarcely more than two or three millimetres in thickness, the flakes, which are obtained by roughly crushing them, are transparent; we have been able to determine, by examining these splinters under the microscope, that they contain no included minerals, and are free from those embedded granules of quartz, to the presence of which M. Laspeyres is inclined to attribute the excessive proportions of silica shewn in some analyses.[3] The thin lamellæ were prepared for

(1) Dela Vallée et Renard. Mém. sur les roches pluton. Mém. Cour. de l' Acad. Roy. de Belgique 1876-7, p. 21, et. seq.

(2) Laspeyres. Min. Bemerk. V. Th. Die chemischen Untersuchungen der Epidot Gruppe. Zeitsch. Kryst. u. Min. III, 5 and 6.

(3) Laspeyres. *loc. cit* pp. 533, et. seq.

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analysis by removing all external impurity; the splinters were then ground down, until the whole was perfectly homogeneous, and was seen, under the microscope, to be free from all foreign matter.[4]

We have found the specific gravity of this epidote to be 3·4211. The specimen analysed contained silica, alumina, protoxide and peroxide of iron, lime, basic water and traces of manganese and magnesia.

The following are the results of our quantitative determinations:
I.—1·0639 grm. of epidote gave 0·0239 grm. of water, 0·4080 grm. of silica, 0·1240 grm. of peroxide of iron, and 0·2646 grm. of alumina.

II.—1·0758 grm. of epidote gave 0·4104 grm. of silica, 0·2651 grm. of alumina, 0·1262 grm. of peroxide of iron, and 0·2542 grm. of lime.

III.—1·1368 grm. of epidote was treated in a sealed tube with hydrofluoric and sulphuric acids, and used for the determination of the protoxide of iron; it was titrated with a solution of permanganate of potash (1cc. = 0·005846 grm. of Fe O), 1·1cc. being required, corresponding to 0·0064 grm of protoxide of iron.

IV.—1·0061 grm. of epidote gave 0·0229 grm. of water.[5]

	I.	II.	III.	IV.	Mean.
$Si O_2$	38·38	38·15	—	—	38·26
$Al_2 O_3$	24·87	24·64	—	—	24·73
$Fe_2 O_3$	11·03	11·11	—	—	11·07
Fe O	—	—	0·56	—	0·56
Ca O	—	23·63	—	—	23·63
$H_2 O$	2·25	—	—	2.27	2·26
Mg O	trace	trace	—	—	trace
Mn O	trace	trace	—	—	trace
					100·51

Before proceeding to establish the formula that may be derived from these analyses, let us examine the generally received theories concerning the composition of epidote; without entering into long discussions, to which the formula of this mineral has given rise, we may content ourselves with stating that, whilst Tschermak[6] and Kenngott[7] have determined it to be $Si_6 Al_6 Ca_4 H_2 O_{26}$, supporting this result by calculations based on a large number of analyses, Rammelsberg[8] has on the

(4) The experiments upon the solubility of epidote in hydrochloric acid, which we shall detail at the end of this paper, will serve to prove that there was no quartz included in the mineral we analysed.

(5) The water was determined according to the method devised by L. Sipöcz (Sitzungsber. d. K. Ak. Wiss. Wien. II, 1877).

(6) Tschermak. Die Feldspathgruppe. Sitzungsber. d. K. Ak. Wiss. Wien 50·585.

(7) Kenngott. Ueber die Zusammensetzung des Epidots. N. Jahresb. 1871, p. 449.

(8) Rammelsberg. Ueber die Zusammensetzung des Epidots von Sulzbach. Zeitsch. Deutsch. Geol. Gesell. 1872, p. 69.

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other hand derived for it the formula $Si_9 Al_8 Ca_6 O_{36}$, founded upon his own analysis of epidote from Sulzbach. Fresh Analyses of the Sulzbach mineral, published by Ludwig [9] proved that the results obtained by Rammelsberg are inaccurate, and that his formula should accordingly b, rejected; Ludwig adheres to the formula of Tschermak and Kenngott, demonstrating its agreement with the results of his analyses of the Sulzbach epidote (Si 0·630, Al, Fe, (as peroxide) 0·615, Ca, Fe, (as protoxide) 0·428, H 0·230, O 2·727). Rammelsberg having since then resumed the examination of the Sulzbach epidote [10] and being guided by his study of Manganese-epidote [11] has abandoned his formula and adopted that of Ludwig [12] which, according to the views of Tschermak and Kenngott consists in regarding this species as an isomorphous mixture of alumina-epidote ($Si_6 Al_6 Ca_4 H_2 O_{26}$) with iron-epidote ($Si Fe_6 Ca_4 H_2 O_{26}$). We shall attempt to shew that the results of our analyses agree with these views.

Taking the mean of all the determinations and calculating out each element we obtain:

Silicon	17·85
Aluminium	13·19
Iron (as peroxide)	7·75
Iron (as protoxide)	0·43
Calcium	16·87
Hydrogen	0·25
Oxygen	42·91

or in atomic proportions:

Silicon	0·6375	
Aluminium	0·4813	0.6196
Iron (as peroxide)	0·1383	
Iron (as protoxide)	0·0075	0.4292
Calcium	0·4217	
Hydrogen	0·2500	
Oxygen	2·6818	

which may be rendered by the formula of Kenngott and Tschermak ($Si.(Al,Fe)_6 Ca_4 H_2 O_{26}$).

Rammelsberg [13] does not take into account in his formula the small

(9) Ludwig. Ueber die chemische Formel des Epidots. Ann. d. Chem. u. Pharm. Vol. 165, p. 217.

(10) Rammelsberg. Ueber die Zusammensetzung der Epidot and Zoisit. Zeitsch d. Deutsch. Geol. Gesell. 24, p. 649.

(11) Rammelsberg. Ueber die Zusammensetzung des Manganepidots. Monatsber. d. Berlin. Ak. 487.

(12) Ludwig. *loc. cit.* p. 223.

(13) Rammelsberg *loc. cit.* Zeitsch d. Deutsch. Geol. Gesell. 1873, 24 .p 69.

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amount of protoxide of iron which is indicated in the analyses; Ludwig[14] also admits that it may be neglected, or regarded, as has been done by ourselves, as isomorphous with lime.

It now remains for us to state the results of our experiments on the solubility of epidote in hydrochloric acid. Most authors admit with Rammelsberg[15] that both epidote and zoisite are completely soluble in this re-agent, if they are first heated to a sufficiently high temperature, but that they are not attacked by it without previous ignition. Laspeyres[16] has recently investigated this question; he has kept epidote, finely powdered, and not previously ignited, boiling on the sandbath in pure hydrochloric acid for 4 or 5 hours a day during several weeks; at the end of this period the mineral was completely decomposed with the production of gelatinous silica. At the same time he adds that the larger particles are only decomposed with great difficulty and that the action of the acid has to be continued for several weeks.

In order to convince ourselves of the solubility of epidote in hydrochloric acid, we have employed a method more expeditious than the above, and which prevents the accidental introduction of foreign matter into the solution, which may easily occur during the above protracted process. This method consisted in heating 0·7833 grm of finely powdered epidote with about two-thirds of fuming and one-third of common hydrochloric acid in a hard glass tube. The sealed tube was kept in the waterbath for a day and then heated for 7 hours to a temperature of 125° to 130°. This was sufficient to completely decompose the mineral, leaving nothing but a white gelatinous mass suspended in the liquid and exhibiting all the characteristics of silica. This was carefully washed by decantation and boiled in a solution of carbonate of soda during half-an-hour, when it dissolved, a few colorless particles alone remaining in suspension. The latter were collected on a filter and were fonnd to weigh 0·002 grm which weight remained constant on treating the residue with hydrofluoric and sulphuric acids.

We have thus proved that the mineral analysed was free from included quartz, and that the above residue even if it had consisted of foreign matter was so small in amount that its presence could not sensibly affect the results of the analyses.

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(14) Ludwig *loc. cit.* p. 221.

(15) For bibliographical references see Laspeyres' article p. 532.

(16) Laspeyres, *loc. cit.* p. 532.

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XVII.—*On Brochantite and its associations.*

By W. Semmons, Past President of the Liverpool Geological Society.

Read December 23rd, 1880.

THE large series of combinations of copper with sulphuric acid found in mineral veins, present many features which call for attentive study.

Some of the series, as Chalcanthite and Pisanite, are easily soluble in water, while others, as Brochantite and the members of the group allied to it, are insoluble therein, and the solubility seems to run in parallel lines with the per centage of copper.

The "Basic" sulphates have of late received considerable notice, and English mineralogists must remember with pleasure that the masterly essay by Prof. Maskelyne "On the minerals of the Brochantite group;" gave us for the first time a clear insight into the characters of some of its constituents. This elaborate paper shewed that the ortho-rhombic varieties were clearly entitled to be divided into distinct mineral species.

As I believe neither the Chilian nor the Peruvian varieties of Brochantite have yet been described in detail, the following notes on a few specimens obtained from some mines near Pisco may be of interest. My attention in examining them was directed partly to their physical and chemical characters and partly to their associations, and for the sake of completeness I have added some notes on the associations of the mineral when found in other localities.

No.1, from near Pisco, consists of an aggregation of crystals of a light emerald-green colour closely compacted together. The crystals run in all directions, but as none of them protrude beyond the surface, I could not obtain any measurement of their angles. An analysis of this specimen was kindly made for me by my friend Mr. H. T. Mannington of Messrs. Muspratt and Son's chemical works, and the results obtained were

Cu O	61·21
S O_3	18·10
C O_2	2·20
Cl	·99
Fe O	·33
Zn O	1·50
$Al_2 O_3$	4·95
$H_2 O$	8·90
Silica (chiefly) &c.	1·82
	100·

Specific gravity 3·32.

This variety being scratched by Calcite, the hardness may be taken as somewhat under 3 on Mohs' scale.

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This aggregation of crystals was met with in a large number of specimens.

The analysis of the above shows it to be intermediate in composition between the Brochantites of which analyses are given in Dana's "System of Mineralogy," and the Cyanotrichites named in the same volume.

In some other specimens, however, a few cavities ("vughs") were met with, and here I found a few crystals. They have the curved appearance and striations generally noticed in crystals of Brochantite, and their resemblance to the crystals of Atacamite found in the same deposits is extremely striking. It is often a matter of difficulty indeed to distinguish one mineral from the other in my specimens, though perhaps the Brochantites are rather lighter in colour than the Atacamites, and are also more transparent.

No. 2 specimen had some crystals 6 m/m in length, and 1 m/m in breadth. As I did not feel sufficient confidence in my measurements of these crystals, I forwarded some to Dr. O. C. Trechmann, and his remarks thereon are appended at the end of this paper. I would here express my obligations to this gentleman for the kindness with which he voluntarily accepted this duty, and the care with which he has executed it.

No. 3 is, in the lower portion of the stone, composed of hemispherical and in some cases almost spherical masses of Malachite of a dark-green colour, the fibres of which are not very closely aggregated together. On these is a layer of an amorphous mineral which is adherent to the tongue. A chemical examination of this amorphous matter shows this to contain both carbonic acid and sulphuric acid in combination with copper. It is in fact an amorphous sulphato-carbonate of copper. This amorphous material, which is of a delicate light bluish-green colour, passes into a darker shade, and at length we meet with a mineral of an emerald-green colour which has the appearance of Malachite, but not its composition. It is sulphate and not carbonate of copper.

A close examination of the light-coloured portion enables one to detect some parts of it which have a fibrous structure, and these pass insensibly into the amorphous variety. It is evidently Malachite decomposing. Though I endeavoured with a lens to pick out pieces in which no structure was visible, I invariably found a slight effervescence with Hydrochloric acid. On its uppermost surface were distinct crystals of Brochantite with the usual well-developed cleavage.

No. 4.—A large specimen which I broke into several pieces shows the replacement of the carbonate by the sulphate still more clearly, as the outer portion of a hemispherical mass was found to be composed of sulphate while the interior is composed of carbonate of copper.

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No. 5 and 6 have beautiful tufts of acicular crystals of Brochantite of a light-green colour, much resembling the tufts of Malachite found with the Ruby ore of New Quebrada Mine, but presents no other features of importance except the occurrence of these crystals in connection with dark-green transparent crystals of Atacamite, which might at first sight be taken for crystals of Brochantite.

Pseudomorphs of Chrysocolla after Brochantite.

No. 7 is a specimen of much importance, and deserves more than a passing notice. It is a mixture of Malachite, Atacamite, and Chrysocolla, the exterior being principally composed of nodules of the first-named mineral. These nodules are coated with a thin layer of Brochantite, and in some places distinct and well-defined crystals of this mineral are seen.—*Some* of the nodules have been decomposed into the amorphous sulphato-carbonate of copper before described, and the whole is then covered by a layer of Chrysocolla. My attention was first attracted by several of the Brochantite crystals being covered by a thin layer of chrysocolla, and on making a very close examination I found that in many instances the original sulphate had been entirely replaced by silicate of copper, and that in fact we had pseudomorphs of Chrysocolla after Brochantite

Conclusions

Looking at these specimens from a paragenetic point of view, one is struck with the association of Brochantite. In my paper on the "Chrysocolla Group" (see Min. Mag. No. 11), I noticed the occurrence of sulphate of copper in connection with silicate of copper, and further examination have shown me that this association is very common, but I find that the sulphate is met with quite as frequently in association with the carbonate of copper in the Chilian ores, and as the instances given at the close of this paper will show, the same close connection is met with in other localities.

The occurrence of Brochantite in Peru associated with the same minerals as at Arizona is important as illustrating its origin.

The ores of copper found with it, malachite, chrysocolla, and atacamite (though perhaps the last should not be used in argument), are all indicative of "change." So too are the sulphates of lime, baryta, and alumina.

Herrengrundite seems to show the combination of the two sulphates of lime and copper, and the elaborate review which appeared in a late number of the Mineralogical Magazine, points to a similar origin for this mineral, namely, the decomposition of other copper ore

With Herrengrundite is found a group of interest
Azurite, Malachite, Petticite, Gypsum.

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With the Brochantite of Laurium we find Azurite, Malachite, Cyanotrichite, Adamine, Aurichalcite and Calamine.

With the Arizona and Chilian Brochantites we meet with Malachite, Chrysocolla, Gypsum, and Barytes.

With the Brochantites of Cumberland we find Malachite and Chrysocolla.

All these "species" are the products of decomposition The occurrence too of these carbonates, sulphates and silicates near the surface, and their general disappearance as we proceed deeper in our mines, point to their being "derived" or "secondary" products.

The important investigations of Field, which prove that chloride of copper can be formed when an alkaline hypochlorite is added to a boiling solution of sulphate, nitrate or chloride of copper, appears to me to throw much light on the frequent association of Gypsum and Barytes with the Brochantites and Atacamites of Chili and Peru. Some specimens I have present layers of Gypsum and Atacamite, much resembling the layers in a stratified rock. "Lyellite" too is shown by Tschermak to be Langite, an important member of the Brochantite group mixed with Gypsum. An analysis of some copper ore from Bolivia, by Mr. W. Terrill, F.C.S., of Morfa Works, Swansea, also bears on this subject. It seems to point to the action of sulphate of copper on a basic feldspar, and the following are the rough results:—

Cu O	14
Ca SO_4	18
$Al_2 O_3$	18
Ca O	11
Si O_2	25
$H_2 O$	12
	98 %

The changes resulting from the decomposition of ores composed of copper, sulphur and arsenic, seem almost endless. It must strike even the most superficial observer as a strange fact, that the sulphates containing copper constitute about one third of the basic sulphates of Dana.

Doubtless, were analyses made, we should obtain a large number of New Minerals, if the replacement of small quantities of copper by other elements constitute the title to a new name.

It was with feelings of regret that I saw the cargo of ore, from which my specimens were derived, consigned to immediate and complete destruction in the crushing mill. Like a botanist witnessing the trampling down of his fairest and rarest flowers, I saw these brilliant gems mangled and crushed.

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Through the kindness of the owners I was, however, enabled to preserve a few specimens, and as some of them are deposited in our grand National Collection, they can be referred to by other Mineralogists; but I cannot help noticing what a vast heap of valuable specimens was here destroyed with scarce a look being bestowed upon it, or fragment preserved.

Observations on the crystals by Dr. Trechmann.

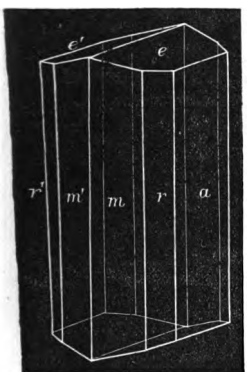

Fig. 1.

Brochantite from Pisco.

The small acicular emerald to dark-green crystals, are so ill-adapted for measurement, on account of the striations and curvatures of the faces, that the following angles can only be regarded as approximations to the truth, but sufficient for fixing the forms.

Retaining for comparison the prismatic system (later researches refer this mineral to the oblique or anorthic systems), I find the following combination of well-known forms, (Fig. 1):

a	100	*r*	210
m	110	*e*	101

Measured Angles.	Brooke and Miller.*	Koksharow.†
$a : m = 52° 43'$	$52° 5'$	T : M = $52° 16'$
$a : r = 32° 33'$	$32° 42'$	T : *l* = $32° 52'$
$a : e = 76° 10'$	$75° 56'$	T : *x* = $76° 19'$

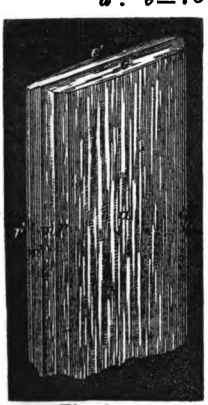

Fig. 2.

All the faces in the prismatic zone are more or less vertically striated, and consequently give to the crystal a curved appearance, which I have tried to represent in Fig. 2. The faces of *e* are slightly curved but not striated.

Similar crystals, also associated with atacamite, chrysocolla, &c., were described by F. A. Genth, (*Am. Journ. of Science*, 1868, p, 321) from Bill Williams' Fork, Arizona.

Fig. 1 is reproduced from Koksharow, Atlas, Plate LIII.

* Brooke and Miller, Mineralogy 1852, p. 553.

† Koksharow, Materialien z. Min. Russlands, III, p. 260.

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Reviews and Notices.

Crystallogenetic Observations by the late Chevalier Charles Von Hauer (Imp. Geolog. Inst., Meeting, June 2nd, 1880.)

Translated by Count Marschall.

Crystals from Solutions of mixed isomorphous combinations.

TWO series of crystalline mixed substances must be distinguished among these crystals. In the *first* place, the mixed solution may be composed of substances possessing in their isolated condition a similar chemical constitution and crystalline form, being thus *à priori* isomorphous.

Such isomorphous combinations are known to crystallize together in relatively very variable proportions. However, in many cases, narrow limits are traced by the different solubility of the component salts. Crystals deposited from a solution of two isomorphous combinations, and allowed to grow for some time, are not of homogeneous composition, if the components are notably different as to their solubility. The less soluble salt predominates in the interior of the crystal, the more soluble one in the superficial portion. If the less soluble component be coloured, the interior will be intensely coloured, the tint gradually vanishing towards the external layers. *Vohl's* so-called "paired double salts" of the Magnium* (sic) group, in their assumed equal-molecule constitution. can be only partly formed in so far as the relations of solubility allow. An obvious exception is that a mixture of isomorphous combinations cannot be brought to crystallize, when the salts, whose solutions are to be mixed, are so composed that their contact must give rise to mutual chemical action.

* "Magnium" was a term used by the author for Magnesium. It is thought better to retain it throughout whenever it appears in the German original.—Ed.

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The specific crystalline form of the salts, belonging to the same isomorphous group, is known occasionally to be very different. In crystallizing any such mixture, either some one salt acts with a certain prevalence, impressing its form on the mixed crystals, or these take a form different from any of the components when crystallising by themselves. In this last case, the mixed crystals exhibit generally less complicated forms than those of their components. Thus, the mixed crystals exhibit constant variations from the forms of their components, together with frequent irregularities, which, by their continuous repetition, give them a distinctive character. In many cases, the relative quantities of the salts in a mixed solution may determine the form of the crystals.

The differences of solubility being such as to make it impossible in many cases to establish any desired predominance of one of the component salts, experiments in this direction are necessarily limited. All therefore that as been said before relates to crystals deposited from a solution of more than two isomorphous salts.

Experiments have been made on the crystallizations out of mixed solutions of ferrid and cobaltid-cyanide of potassium, the double nitrates of cerium with nickel and manganese, and the double oxalates of iron, chromium, and aluminium, with ammonium, potassium or sodium. The individual members of each of these groups of isomorphous combinations, when isolatedly crystallized, form a group as well defined as the group of the alums, and similarly exhibit certain aberrations from symmetry and slight irregularities. Other subjects of investigation were solutions of double sulphates of the magnium group and potassium, in which variable quantities of sulphuric acid were replaced by chromic acid. The crystals from these solutions, which are isomorphous with the first of these salts, exhibit constantly a "habitus" quite different from that of the double sulphate of magnesia and potash, provided chromic acid has been added in sufficient proportion. The rhombic prisms of this monoclinic salt, in this last case, appear notably shortened, and the terminal surfaces are unusually extended, the crystals assuming thus a tabular form. If chromic acid, instead of sulphuric acid, is introduced into the sulphate of magnesia-ammonia, the crystals undergo no perceptible change.

The cobaltid-cyanide of potassium, like the analogous iron compound, appears invariably in twin crystals, like those formed from a mixture of both these combinations, which Mr. Kopp pronounces to be monoclinic, and Messrs. Schabas and Rammelsberg consider as rhombic.

The crystals from a mixture of cero-manganese and cero-nickel nitrates exhibit a hexagonal tabular form with two extra faces on the edges, like those of their components, the nickel salt showing fr

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truncated edges and angles. These crystals are nearly uncoloured, when the manganese salt prevails; in the opposite case they are light-green, diaphanous, and will easily grow to a considerable size. Their hexagonal character is not yet duly ascertained.

The oxalates of chromium and ammonium or potassium and iron-ammonium deposit out of their mixed solutions bluish-green crystals, which may be allowed to grow large without impairing the perfection of their form. They are exactly identical in form with those of their components. Their transparency is secured by carefully arranging the predominance of the iron salt in the mixture. They are somewhat less sensitive to the action of light than those of the isolated iron salt.

Chemical literature offers but scanty details concerning the double combinations of oxalate of alumina with ammonia, potash, and soda. C. Gerhardt, in his "Treatise of Organic Chemistry," says "The solution of alumina in binoxalate of potash, when slowly evaporated, and especially when a stratum of spirit of wine is spread over it, produces thin lamellæ." These salts are obtained in well formed, transparent, colourless crystals, an inch long, by repeated solution and crystallization. When hydrate of alumina is dissolved in a solution of binoxalate of potash under the action of heat, then evaporated and left to cool, nothing is obtained but crystalline crusts and bubbles, which are aggregations of thin lamellæ. If a notable proportion of the simple alkaline oxalate be added to this solution, it at once produces crystals on concentration. The original solution has always a yellow tint; the crystals, purified by repeated solution and crystallization, give a colourless solution. Good crystals are easily obtained by moderate artificial, or by natural, evaporation,—the use of alcohol is not absolutely necessary.

The re-crystallization of the oxalates here in question does not require another addition of alkaline oxalate, as is the case with the other double salts, which cannot be re-crystallized without decomposition, except in presence of an excess of one of their components. It may thus be supposed that the double oxalates of alumina differ in composition from those of the sesquioxides of iron and chromium. However, both are undoubtedly of similar crystalline form, and their crystalline equivalence is proved by the fact that the double oxalates of alumina, when mixed with those of iron and chromium, yield crystals of the same form as those of the last-named oxalates.

According to Baron Foullon's investigations, the double oxalates of iron and chromium have not yet been accurately investigated. Mixtures of oxalates of iron with those of alumina produce light yellowish-green crystals. Exceedingly beautiful crystals are obtained by dissolving

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together one of the alumina compounds together with the chrome salt. According to the mutual proportion of the ingredients these crystals, which may be obtained in very large size, are more or less intensely violet, reflecting rays of ruby-red light.

Another series of crystals from mixtures of isomorphous combinations arises from mechanical mixtures of salts, which, when crystallized separately are either not similar in chemical composition, or identical in crystalline form, or are even dissimilar in both respects, not being isomorphous *á priori*, and only becoming so when crystallizing out of a mixed solution. The sulphates of magnium and cobalt, mixed in very various proportions, are crystallizable in the form of sulphate of magnesium. Both these sulphates are of a similar chemical composition, as they both crystallize with 7 atoms of water; however, the sulphate of magnium is *rhombic*, and the sulphate of cobalt is *monoclinic*, in the form of green vitriol. In a mixture of both, however, the sulphate of cobalt becomes a crystalline equivalent to the sulphate of magnium, and is thus proved to be dimorphous.

The crystallization of the double sulphate of potassium and manganese offers a striking instance of the way in which a combination mixed with another may change its chemical constitution and crystalline form, and thus become a crystalline equivalent to the latter combination. This double sulphate crystallizes with 4 atoms of water, and in a form quite different from that of the double sulphates of the magnium group.

The existence of a double sulphate of potassium and manganese with 6 atoms of water, as mentioned by several chemists, seems to rest on mere supposition. It may be, indeed, worth notice, that among the numerous series of isomorphous double sulphates of the magnium group, the non-existence of this single combination constitutes a "hiatus." This exception is the more remarkable, as there exists a double sulphate of potassium and ammonium with 6 atoms of water.

A solution of the potassium salt mixed with another of the magnium group, gives rise to crystals isomorphous in composition and form to those of this group. A dimorphism of the double sulphate of potassium and magnium is out of question in this case, as the combination, passing into a new form, changes its chemical constitution. The experiments of Professor Rammelsberg, on crystallizations out of mixed solutions of sulphates of copper and iron, of sulphates of iron and magnium, &c., have proved that in such cases, when a mixture of two isomorphous salts crystallizes isomorphously with one of them, the relative quantity of this salt determines the mode of crystalline metamorphosis.

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It appears from what has been said, that the comparative chemical and crystallographical examination of two salts in itself, does not always show how far they are isomorphous, or rather crystallographically equivalent, or may become so. The question must be decided by way of experiment. A notable difference exists between the dimorphism of a substance, manifested by its appearance in a pure state in two different crystalline forms, and the other dimorphism in which, only mixed with another substance, it assumes a crystalline form other than the one peculiar to it. The first form of dimorphism may be called "primary," the other "secondary." No doubt many substances will prove dimorphous in the latter way; this, however, can only be ascertained by empirical experiments. The more instances are known, in which a substance with unchanged composition is able to adopt different crystalline forms, the more difficult becomes the question concerning the connexion between chemical constitution and crystalline form.

Episomorphous Crystals. The successive deposition, in one and the same crystal, of compounds, frequently very different in quality, colour, and even in specific form and number of surfaces, has a particular interest. While in naturally crystallized minerals such occurrences are but rare, crystals produced in laboratories offer them frequently in the most conspicuous variations and in the highest perfection of form. The superposition of two compounds is the surest criterion of the crystalline affinity, and more to be relied upon than identity of form or similitude of chemical composition.

The Museum of the Imperial Geological Institute numbers several hundred specimens of varied episomorphous crystals, conspicuous by their size and perfection. The groups of episomorphous combinations, among whose terms superpositions have succeeded, are: (1) the alums; (2) the vitriols; (3) the mixtures of sulphate of magnium with other sulphates; (4) the sulphates and chromates; (5) the double combinations of oxalic acid; (6) the double nitrates of cerous oxide; (7) the ferrid—and cobaltid—cyanides of potassium; (8) the chlorate and bromate of soda.

It results from what has been said before about crystallizations of mixed isomorphous combinations, that superpositions of isolated salts can only take place among the terms of the first series of isomorphous combinations, each term of two isomorphous salts of the second series being a mixture of this term with another salt. The mere introduction of a crystal of one salt into a solution of another will not produce a change of form, although if the two salts be mixed *in solution* the former —" be modified by the latter. Thus, a crystal of sulphate of iron grow in a solution of sulphate of magnium, although, in a mixed

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solution of both these sulphates, a crystalline mass, isomorphous with green vitriol, is deposited.

Of course, the order, according to which the superposition of salts of an isomorphous group takes place, depends on their relative solubility. However, if the solubility of two combinations is not very different, a superposition of the less soluble salt over a crystal of the more soluble one is possible. In this case the saturated solution of the second salt should be mixed with a small proportion of the more soluble one, then the crystal should be introduced into solutions gradually containing less and less proportions of the more soluble salt, and at last into the pure solution of the less soluble one. This operation is promoted by keeping the vessel, in which the crystallization goes on, at a temperature somewhat inferior to that at which the solutions have been prepared. In this way beautiful crystals of potassium-magnium-chromate-sulphate, with superposition of potassium-magnium-sulphate, have been obtained.

Crystals of simple and mixed salts from an isomorphous group may be superposed in any order by mixtures of salts of the same group, when as much of the most soluble salt as they are able to take up is added to the solutions. If the process of superposition is sufficiently continued, the specific "habitus" of the superposed substance, which it shows when isolated, comes out. Such observations tend to prove clearly what is variable in the special form of such crystals, and what is a fundamental crystallographical character of the substance in question.

The degrees of solubility of the double oxalates in question are represented by the following series:—chrome, iron, aluminium. Crystals have been obtained, in which all these three compounds are superposed on each other. An addition of the double oxalate of alumina and ammonia serves for the saturation of the solutions for all these crystals. The superposed substances are separated from each other by very distinct stratification. Crystals of salts of chromium, and of chromium and aluminium, on which the oxalate of aluminium is superposed, are particularly beautiful.

Chrome alum is somewhat more soluble than common potash alum. A good method of obtaining a superposition of this last alum over the first one, is to leave at first crystals of chrome alum in a solution of cubic alum (alumina alum with an addition of ammonia) in which they are not soluble, and when a stratum of cubic alum is deposited on them, to immerge them in a solution of common alum. The cubic surfaces formed at first, disappear again in the second solution.

The crystals of ferrid-cyanide of potassium increase with extreme rapidity along the axis of the prisms, while the diameter of the latter

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increases very slowly. The same is the case with the cobaltid-cyanide of potassium. If crystals of the ferrid-cyanide are left to increase in a solution of cobaltid-cyanide, the ends of the crystal will, in a short time, show prolongatious of the yellow cobaltid-cyanide, scarcely any superposition being apparent on the prismatic surfaces. The ferrid-cyanide is somewhat more soluble than the cobaltid-cyanide; however, by arranging the temperature, the superposition may be effected.

The double nitrates of cerium and nickel and of cerium and manganese are not materially different as to their solubility. Their superposition proceeds far more rapidly along the edges of the hexagonal tabular crystals than on their surfaces. At first, green tabular crystals with a broad red margin (or the reverse) are obtained, the superposition over the whole of the crystals progressing very slowly. Chloride of sodium being added to the mixture of both these double salts, crystals are obtained out of the solution, which are neither cubes nor tetrahedrons, but present a new form, resembling those of nitrate of lead.

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